NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 4283

FULL-SCALE WIND-TUNNEL TESTS OF A 35° SWEPTBACK-WING AIRPLANE WITH BLOWING FROM THE SHROUD AHEAD OF THE TRAILING-EDGE FLAPS

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SUMMARY

A wind-tunnel investigation was made at full scale to determine the effect of flap location on the jet-flow momentum coefficient required to control the flap boundary layer when blowing from the wing shroud. The tests were made on a 35° sweptback-wing airplane at a Reynolds number of 7.5×10^6, based on the mean aerodynamic chord, with flap deflections of 45°, 60°, and 75° and with pressure ratios across the blowing nozzles from 1.0 to 2.9. The data presented show the change in lift coefficient with changes in momentum coefficient for the various flap deflections, flap positions, and nozzle heights.

The results showed that flap locations near the nozzle permitted control of the flap boundary layer with minimum jet-momentum requirements; with increasing distance of the flap from the nozzle, the momentum required for boundary-layer control increased rapidly. The momentum-coefficient requirements for shroud blowing with a plain flap (no slot) compare favorably with the requirements for blowing from a nozzle located in the upper surface of a plain flap.

The jet momentum coefficient was not a satisfactory correlating parameter for blowing with large nozzle heights and low duct pressures. Better correlation was obtained for low-pressure blowing when the ratio of local velocity at the nozzle to free-stream velocity was included in the correlating parameter.

INTRODUCTION

The tests of reference 1 were concerned with controlling the boundary layer on a plain-type flap by blowing a high-velocity jet of air across the flap from a nozzle located in the flap upper surface near its leading edge. Boundary-layer control on the flap can also be achieved by blowing from a nozzle located in the wing shroud just ahead of the flap. When the nozzle is located in the flap (flap blowing) changes in flap deflection or position do not change the position of the nozzle relative to the flap. However, when the nozzle is located in the wing shroud (shroud blowing) any change in flap deflection or position affects the nozzle-flap relationship. Data from two-dimensional tests of references 2 and 3 indicate that with shroud blowing there is a pronounced effect on the amount of air flow required for boundary-layer control when the flap position is changed relative to the nozzle. These references do not, however, define the extent of flap positions in which boundary-layer control can be obtained with minimum air-flow requirements.

The purpose of this test was to determine the effect of flap position on the air-flow requirements of the shroud blowing flap, and also to make a direct comparison of shroud blowing and flap blowing on the same airplane with the plain-flap configuration. It was also desired to determine the validity of using the momentum of the jet air flow as the correlating parameter when the velocity of the jet approached the local velocity over the flap. Data were obtained in the plain-flap configuration showing the effect on the air-flow requirements of spacers in the nozzle and of discontinuities on the flap upper surface. Data also were obtained showing the effects of sealing the slot when the flap was in the single-slotted flap configuration.

SYMBOLS AND NOTATION

C_{BLC}	blowing jet boundary-layer-control parameter, $C_\mu' - 2C_Q \frac{U}{U_\infty}$
C_L	lift coefficient, $\frac{\text{lift}}{q_\infty S}$
C_Q	blowing jet flow coefficient, $\frac{W_j}{wU_\infty S}$
C_μ	blowing jet momentum coefficient, $\frac{W_j/g}{q_\infty S} V_j$
C_μ'	corrected blowing jet momentum coefficient
c	wing chord parallel to plane of symmetry, ft
$\bar{c}$	wing mean aerodynamic chord, $\frac{2}{S}\int_0^{b/2} c^2 dy$, ft
F_G	gross thrust from engine, $\frac{W_E V_{TP}}{g}$, lb

F_N net thrust from engine, $F_G - \frac{W_E U_\infty}{g}$, lb

g acceleration of gravity, 32 ft/sec^2

h_s nozzle height, in.

L.E. leading edge

p static pressure, lb/sq ft

p_{t_d} total pressure in wing duct, lb/sq ft

q dynamic pressure, lb/sq ft

R gas constant for air, 1715 ft^2/sec^2, $^\circ$R

S wing area, sq ft

T total temperature, $^\circ$R

U velocity, ft/sec

V_{TP} velocity at tail-pipe exit, ft/sec

V_j jet velocity assuming isentropic expansion,

$$\sqrt{\frac{2\gamma}{\gamma-1} RT_d \left[1 - \left(\frac{p_\infty}{p_{t_d}}\right)^{\frac{\gamma-1}{\gamma}}\right]}, \text{ ft/sec}$$

W weight rate of flow, lb/sec

w specific weight of air at standard conditions, 0.0765 lb/cu ft

y spanwise distance normal to plane of symmetry, ft

z vertical distance of flap upper surface from nozzle center line, in.

α angle of attack of fuselage reference line, deg

γ ratio of specific heats, 1.4 for air

δ_f flap deflection, measured in a plane normal to flap hinge line, deg

θ angle between engine tail pipe and fuselage reference line, deg

Subscripts

∞	free stream
d	wing duct
E	engine
j	jet
u	uncorrected

MODEL AND APPARATUS

Airplane

The model tested was the same YF-86D airplane tested in reference 1 and is shown mounted on the three-strut support system in the Ames 40- by 80-foot wind tunnel in figure 1. Figure 2 shows the major dimensions and geometry of the airplane. Details of the wing are presented in figure 3. The wing airfoil section was an NACA 0012-64 (modified) at the root and an NACA 0011-64 (modified) at the tip. The coordinates of these sections are given in table I. The standard wing leading-edge slats were retracted and sealed and the horizontal tail was removed for this test.

Flaps

The flap position, with respect to the nozzle, was made continuously adjustable vertically and in the fore and aft directions (normal to the hinge line) by means of threaded screws in the mounting brackets. The deflection angle was set by an indexing device located at the point of rotation.

The flap position is defined by its vertical position above or below the center line of the nozzle and by the gap between the nozzle and the flap. This gap was measured when the upper surface of the flap was tangent to the nozzle center line as shown in figure 4(a). However, when the flap was moved vertically, no fore and aft adjustment was made and, as a result, the gap varied with vertical displacement of the flap from its reference position at the nozzle center line, as shown by the dotted outlines in figure 4(a). Table II shows the flap positions tested at the various flap-deflection angles.

Flap Nozzles

The flap nozzle was located at the juncture of the wing upper surface and the wing shroud liner just ahead of the leading edge of the flap (fig. 4(a)). The nozzle blocks were machined from cold rolled steel and were fastened with countersunk machine screws directly to the wing upper surface skin and to the skin of the shroud liner. The nozzle opening or height was adjusted by inserting 0.32-inch wide spacers of the desired thickness every 2 inches along the span of the nozzle (fig. 4(b)). This arrangement allowed adjustment of the nozzle height within ±0.001 inch of the designated height. The variation of nozzle height due to changes in temperature and pressure were negligible. All tests were made with the spacers at 2-inch intervals except where noted. Figure 4(c) shows the shroud blowing flap with the spacers at 6-inch intervals.

Engine and Ducting

For this test, the J-47 turbojet engine normally used in the airplane was replaced by a J-34 engine which was modified for blowing flap operation. The air supply for the flaps was obtained by bleeding air off the engine compressor. These modifications are discussed in detail in reference 1.

The arrangement of the ducting from the engine was the same as in the tests of reference 1, with the exception that the ducting was carried into the wing instead of the flap. In the wing, the nozzle ducting was formed as shown in figure 4(a) by the upper and lower wing surface skin, the shroud skin, and the wing spar. It was braced internally by spanwise stiffeners with large lightening holes to permit free flow of the air. The shroud skin was also braced externally by 1/2-inch square formed ribs spaced approximately 10 inches apart.

The weight rate of flow to each flap was obtained from total pressure, static pressure, and temperature measured at a point downstream of the engine bleed manifold. This system was calibrated with a standard thin-plate orifice. The jet momentum was calculated from total pressure and temperature measured in the duct at the wing root juncture.

TESTS

Range of Variables

The tests were conducted at a Reynolds number of 7.5×10^{6}, based on the mean aerodynamic chord, which corresponded to a dynamic pressure of

25 pounds per square foot. The flap deflection angles tested were 45°, 60°, and 75° with the nozzle heights ranging from 0.018 to 0.184 inch. The ratio of duct pressure to free-stream pressure was varied from 1.0 to 2.9 with the total weight rate of flow to both flaps varying from 0 to 8.2 pounds per second.

These tests were conducted at angles of attack of 0° and 12° for the flap deflected to 45° and 60°, and 0° and 8° for the flap deflected to 75°.

Engine Thrust Measurement

Since the air supply for the blowing nozzle was bled from a turbojet engine mounted in the fuselage, it was necessary to determine the engine thrust in order to correct the measured force data. The gross thrust was obtained from a thrust calibration using the tunnel balance system. The net thrust was obtained by subtracting the ram drag from the gross thrust, as follows:

$$F_N = F_G - \frac{W_E U_\infty}{g}$$

The weight rate of flow through the engine, W_E, was determined from pressure and temperature measurements at the compressor inlet. A more detailed discussion of these measurements will be found in reference 1.

CORRECTIONS

The force data obtained from the wind-tunnel balance system were not corrected for support-strut interference. The angle-of-attack designation throughout this report is uncorrected for wind-tunnel wall effect. For specific values of lift coefficient, the geometric angle of attack may be corrected by $\alpha_{corr} = \alpha + 0.611 C_L$. The force data were corrected for the effect of engine thrust as follows:

$$C_L = \frac{\text{total lift}}{q_\infty S} - \frac{F_N}{q_\infty S}\sin(\alpha + \theta)$$

The effect on the lift of turning the intake air at the inlet was found to be negligible and was not included in the corrections.

RESULTS AND DISCUSSION

Effect of Flap Position on the Momentum Requirements

Figures 5 and 6 show the effect of changing the flap position on the C_μ requirements of the flap for deflections of 45° and 60° at 0° and 12° angle of attack. Figure 7 shows similar data for the flap deflected to 75° at 0° and 8° angle of attack.

In this report, as in reference 1, C_μ for attachment is defined as the C_μ employed when the flow over the flap first became attached as indicated by static-pressure measurements near the flap trailing edge at three spanwise stations. In figures 5 through 7, short vertical lines have been placed on the curves at the point where the pressure data indicated that the flow first became attached. There are some instances where a data point was not obtained at the C_μ for attachment. In these cases the vertical lines indicate the point of attachment as estimated from the static-pressure measurements. Curves for which flow attachment was not obtained are left unmarked. Vertical lines have also been used to show the C_μ for attachment when the flap was in the most efficient position for each deflection angle.

It is seen in figures 5 through 7 that the lowest C_μ for attachment was obtained when the flap was in the plain flap position. When the gap was increased to 0.44 inch, the C_μ for attachment showed little change. At the 0.44-inch gap position, there was no change in the required C_μ when the vertical position was changed to ±0.25 inch from the nozzle center line for the flap deflected 60° nor for the -0.25-inch position for the flap deflected 75°. When the gap was increased to 1.06 inches and 2.44 inches, the C_μ for attachment increased markedly. At the 2.44-inch gap position, however, slightly less C_μ was required for attachment when the flap was positioned above the nozzle center line than when it was tangent to the nozzle center line.

At the higher flap deflections, the C_μ for attachment was more sensitive to changes of the flap position in the vertical direction. For each gap, at flap deflections of 60° and 75°, the C_μ for attachment increased rapidly when the flap was moved to vertical positions which were greater than ±0.25 inch from the flap position for least C_μ for attachment.

Figures 8(a) and (b), cross plots of the preceding data, show the variation with gap of the minimum C_μ for attachment and the vertical position at which the minimum C_μ was obtained.

Comparison of Shroud Blowing and Flap Blowing

A comparison of shroud blowing and flap blowing is shown in figure 9 for the flap deflections of 45°, 60°, and 75°. The nozzle height was 0.064 inch in both cases with no nozzle spacers and with the plain-flap configuration. The data for the flap-blowing configuration were taken from figure 7(b) of reference 1.

The comparison shows that the C_L versus C_μ characteristics are about the same when the best of the shroud-blowing configurations is compared with the flap-blowing configuration. This result would seem logical since the best position of the shroud-blowing flap has zero gap and therefore simulates the plain-flap configuration with flap blowing.

It is concluded from the foregoing data and comparisons that with shroud blowing the plain-flap configuration is more efficient than the single-slotted flap. It is also concluded that with the plain-flap configuration, the relation between C_L and C_μ for shroud blowing and for flap blowing is essentially the same. The choice of the type of blowing would probably be determined from mechanical or structural considerations rather than from momentum-requirement considerations. The results of these tests also indicate that when shroud blowing was used with the flap positioned within 0.44 inch of the nozzle and within ±0.25 inch vertically of the nozzle center line, as low a C_μ for attachment was obtained as with flap blowing on the plain-flap configuration. Flap positions outside of this area result in large increases in C_μ for attachment.

Correlation of Momentum Coefficient for Various Nozzle Heights

References 1 and 4 indicate that C_μ may be used as a correlating parameter in the determination of the air-flow requirements of a blowing flap. In these two references, correlation with C_μ is obtained for nozzle heights from 0.006 through 0.065 inch. Reference 2 presents data which indicate that correlation with C_μ is not obtained at larger nozzle heights.

For the present test, the nozzle was constructed so that the height could be varied from 0.018 to 0.184 inch. The smallest height allowed just enough C_μ for attachment at the maximum pressure ratio available and at a free-stream dynamic pressure of 25 pounds per square foot. The largest height was designed to exceed the nozzle range tested in reference 2.

Figure 10(a) shows the change in variation of C_L with C_μ for the various nozzle heights tested with the flap in the plain-flap position at 60° deflection. The correlation of C_μ is within 15 percent for the nozzle height range from 0.018 to 0.064 inch which is about the same order of correlation that was obtained by the tests of reference 1. At larger nozzle heights, the correlation becomes progressively worse and at a height of 0.184 inch the C_μ for attachment is more than twice that at a height of 0.018 inch.

One reason for the lack of correlation at the larger nozzle heights was probably that the cross-sectional area of the duct was of the same order of magnitude as the spanwise cross-sectional area of the nozzle, the area ratio having been 1.05 to 1.0 for the 0.184-inch nozzle with nozzle spacers. This resulted in high duct velocities with correspondingly high losses so that the pressures and temperatures measured at the duct entrance were not representative of the conditions at the nozzle. At the smaller nozzle heights where the correlation is good the area ratio for the 0.018-inch nozzle was 11.1 to 1.0 and for the 0.064-inch nozzle, 3.0 to 1.0. In this range of area ratios the duct velocities and losses were greatly reduced and the conditions at the duct entrance closely approximated those at the nozzle. When the data measured at the duct entrance were corrected to the conditions at the nozzle, as determined by total pressure and temperature probes, the correlation was improved somewhat. This is shown in figure 10(b) as a plot of C_L versus C_μ'. Here it is seen that good correlation was obtained for all but the two largest nozzle heights.

Static-pressure measurements on the surface of the flap near the nozzle indicated that when the C_μ was 0.010 the ratio of the jet velocity to the local velocity for the 0.184-inch nozzle was approximately 1.8 whereas the velocity ratio for the 0.018-inch nozzle was 3.9. The theory of reference 5 indicates that for low velocity ratios the jet momentum alone may not be the correlating parameter and that the velocity ratio must also be considered. Therefore, the corrected data of figure 10(b) were used to compute the parameter, C_{BLC}, as outlined in reference 5, where

$$C_{BLC} = C_\mu' - 2C_Q \frac{U}{U_\infty}$$

and U is the local stream velocity over the nozzle.

The results of this computation are shown in figure 10(c) as a plot of C_L versus C_{BLC}. Here it is seen that the correlation of C_L with C_{BLC}, although not exact, is much better than with C_μ' for the largest nozzle tested.

Effect of Some Nozzle and Flap Configurations on C_μ Requirements

Spacers in the nozzle.- Figure 11 shows the effect on the C_μ for attachment of spacers 0.32 inch wide at various spanwise intervals inside the nozzle. When spacers were at 6-inch intervals there was no appreciable change in the C_μ for attachment. When the interval was reduced to 2 inches, however, there was a significant increase in C_μ for attachment and also a decrease in lift due to boundary-layer control.

Single wide blockage in nozzle.- In order to simulate the effect of an interruption of the nozzle by some device such as an actuator or hinging device, a spacer 6 inches wide was inserted into the nozzle at midspan of the flap. This resulted in a large loss in lift, as shown in figure 12. Tuft studies indicated that this result was due to a large stalled area on the flap beginning directly behind the blockage and spreading spanwise so that approximately a third of the span of the flap was stalled at the trailing edge. In an attempt to alleviate this condition, the inboard and outboard edges of the blockage were tapered to a span of 5.25 inches at its trailing edge but the stall persisted as before.

Discontinuity on the flap upper surface.- Discontinuities formed from metal strips 0.125 and 0.25 inch thick extending the full span of the flap were placed 6 inches from the nozzle, measured on the surface of the flap when it was deflected to 60°. Figure 13 shows the effect of these discontinuities on the C_L, C_μ relationship. The 0.125 discontinuity required approximately 80-percent more C_μ for attachment than was required by the smooth flap, while with the 0.25-inch discontinuity it was not possible to obtain flow attachment on the flap at the maximum C_μ available.

In the tests of reference 1 similar discontinuities behind the flap blowing nozzle required much less increase in C_μ for attachment, indicating that the shroud blowing flap is more sensitive to discontinuities than flap blowing. The reason for this is not understood at this time.

Gap seal.- Figure 14 shows the effect on C_μ for attachment when the gap between the wing and flap was covered by a seal plate on the lower surface. With the 1.06-inch gap there was a small reduction in C_μ for attachment but with the 2.44-inch gap the seal plates reduced the C_μ for attachment to less than one-half the value required with no seal.

It might also be noted here as well as in figures 6(d) and 7(d) that at this large gap position, the lift at $C_\mu = 0$ is considerably lower than at the other gap positions. With the gap sealed, however, the lift was increased almost to the value for the smaller gap positions.

CONCLUDING REMARKS

From the tests of the shroud blowing flap on the YF-86D airplane, it was found that:

1. The minimum C_μ required to attach the flow over the flap was attained when the gap between the nozzle and the flap was 0.44 inch or less and the upper surface of the flap was located vertically within ±0.25 inch of the nozzle center line.

2. At flap positions outside these limits, the C_μ requirements increased rapidly with increasing distance.

3. Increasing flap deflection increased the sensitivity of the C_μ requirements to flap position.

4. Shroud blowing compared favorably with flap blowing when used on the plain-flap configuration.

5. The jet-momentum coefficient was not a correlation parameter throughout the nozzle-height range tested. In order to obtain better correlation between the data of the large nozzle heights and those of the smaller nozzle heights, it was necessary to include the ratio of the local velocity at the nozzle to free-stream velocity in the correlating parameter.

Ames Aeronautical Laboratory
National Advisory Committee for Aeronautics
Moffett Field, Calif., Jan. 29, 1958

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3. Harkleroad, E. L., and Murphy, R. D.: Two-Dimensional Wind-Tunnel Tests of a Model of an F9F-5 Airplane Wing Section Using a High-Speed Jet Blowing Over the Flap. Part I - Tests of a 6-Foot Chord Model. DTMB Rep. Aero. 845, May 1953.

4. Kelly, Mark W., and Tucker, Jeffrey H.: Wind-Tunnel Tests of Blowing Boundary-Layer Control With Jet Pressure Ratios up to 9.5 on the Trailing-Edge Flaps of a 35° Sweptback-Wing Airplane. NACA RM A56G19, 1956.

5. Kelly, Mark W.: Analysis of Some Parameters Used in Correlating Blowing-Type Boundary-Layer Control Data. NACA RM A56F12, 1956.

TABLE I.- COORDINATES OF THE WING AIRFOIL SECTIONS NORMAL TO THE WING QUARTER-CHORD LINE AT TWO SPAN STATIONS

[Dimensions given in inches]

Section at 0.467 semispan			Section at 0.857 semispan		
Distance from L.E.	Ordinate		Distance from L.E.	Ordinate	
	Upper	Lower		Upper	Lower
0	0.231	---	0	-0.098	---
.119	.738	-0.307	.089	.278	-0.464
.239	.943	-.516	.177	.420	-.605
.398	1.127	-.698	.295	.562	-.739
.597	1.320	-.895	.443	.701	-.879
.996	1.607	-1.196	.738	.908	-1.089
1.992	2.104	-1.703	1.476	1.273	-1.437
3.984	2.715	-2.358	2.952	1.730	-1.878
5.976	3.121	-2.811	4.428	2.046	-2.176
7.968	3.428	-3.161	5.903	2.290	-2.401
11.952	3.863	-3.687	8.855	2.648	-2.722
15.936	4.157	-4.064	11.806	2.911	-2.944
19.920	4.357	-4.364	14.758	3.104	-3.102
23.904	4.480	-4.573	17.710	3.244	-3.200
27.888	4.533	-4.719	20.661	3.333	-3.250
31.872	4.525	-4.800	23.613	3.380	-3.256
35.856	4.444	-4.812	26.564	3.373	-3.213
39.840	4.299	-4.758	29.516	3.322	-3.126
43.825	4.081	-4.638	32.467	3.219	-2.989
47.809	3.808	-4.452	35.419	3.074	-2.803
51.793	3.470	-4.202	38.370	2.885	-2.574
55.777	3.066	-3.891	41.322	2.650	-2.302
59.761	2.603	-3.521	44.273	2.374	-1.986
[a]63.745	2.079	-3.089	[a]47.225	2.054	-1.625
83.681	-.740	---	63.031	.321	---
L.E. radius: 1.202, center at (1.201, 0.216)			L.E. radius: 0.822, center at (0.822, -0.093)		

[a]Straight lines to trailing edge.

TABLE II.- FLAP POSITIONS TESTED

δ_f, deg	Gap, in.	z, in.					
45	0			0			
	1.06	0.50		0		-0.50	-0.69
	1.75			0		-.50	
60	0			0			
	.44	.50	0.25	0	-0.25		-.75
	1.06	.50	.25	0	-.25		
	2.44	.50		0	-.25		
75	0			0			
	.44			0	-.25		
	1.06		.25	0	-.25	-.50	
	2.44	.55		0	-.25		

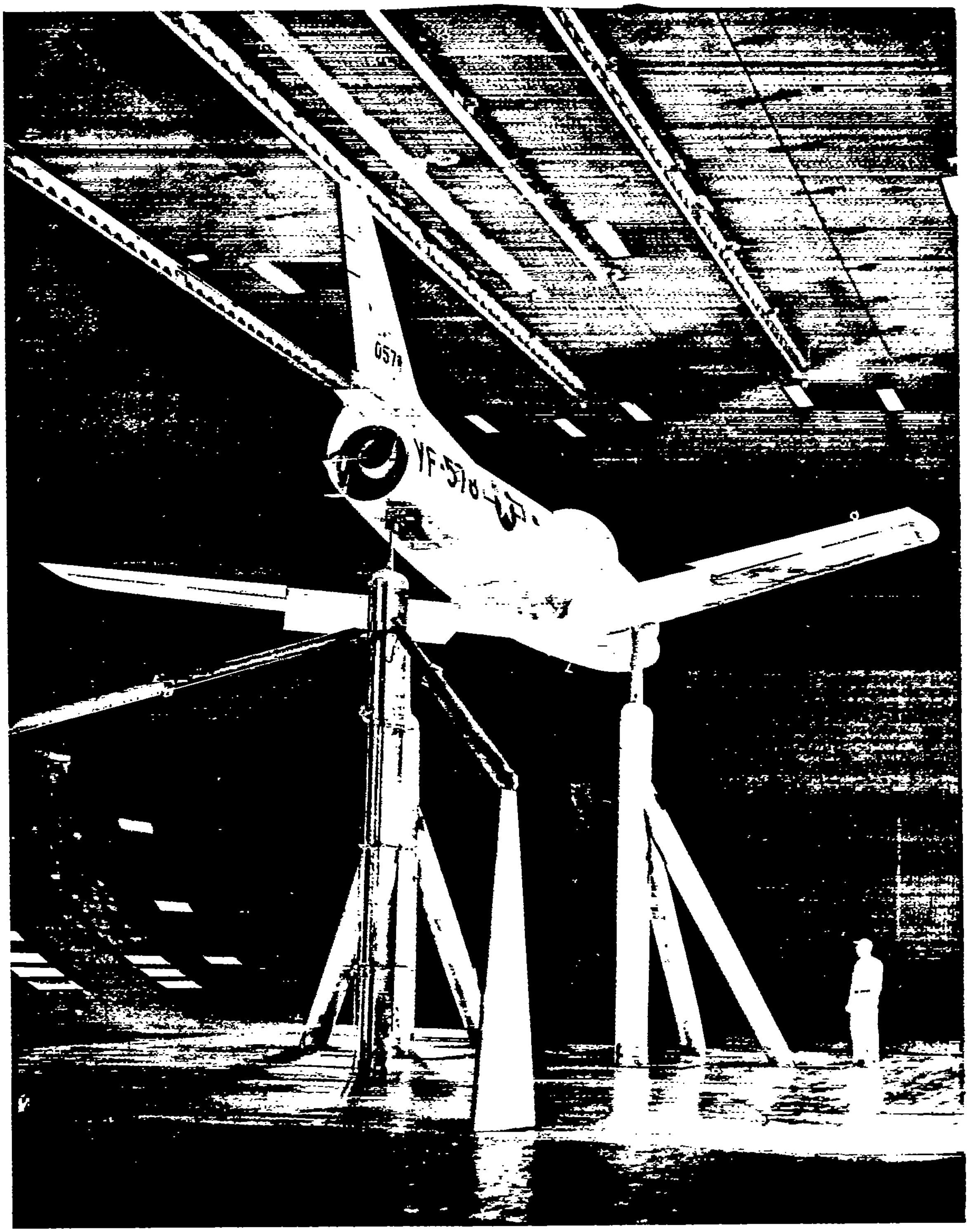

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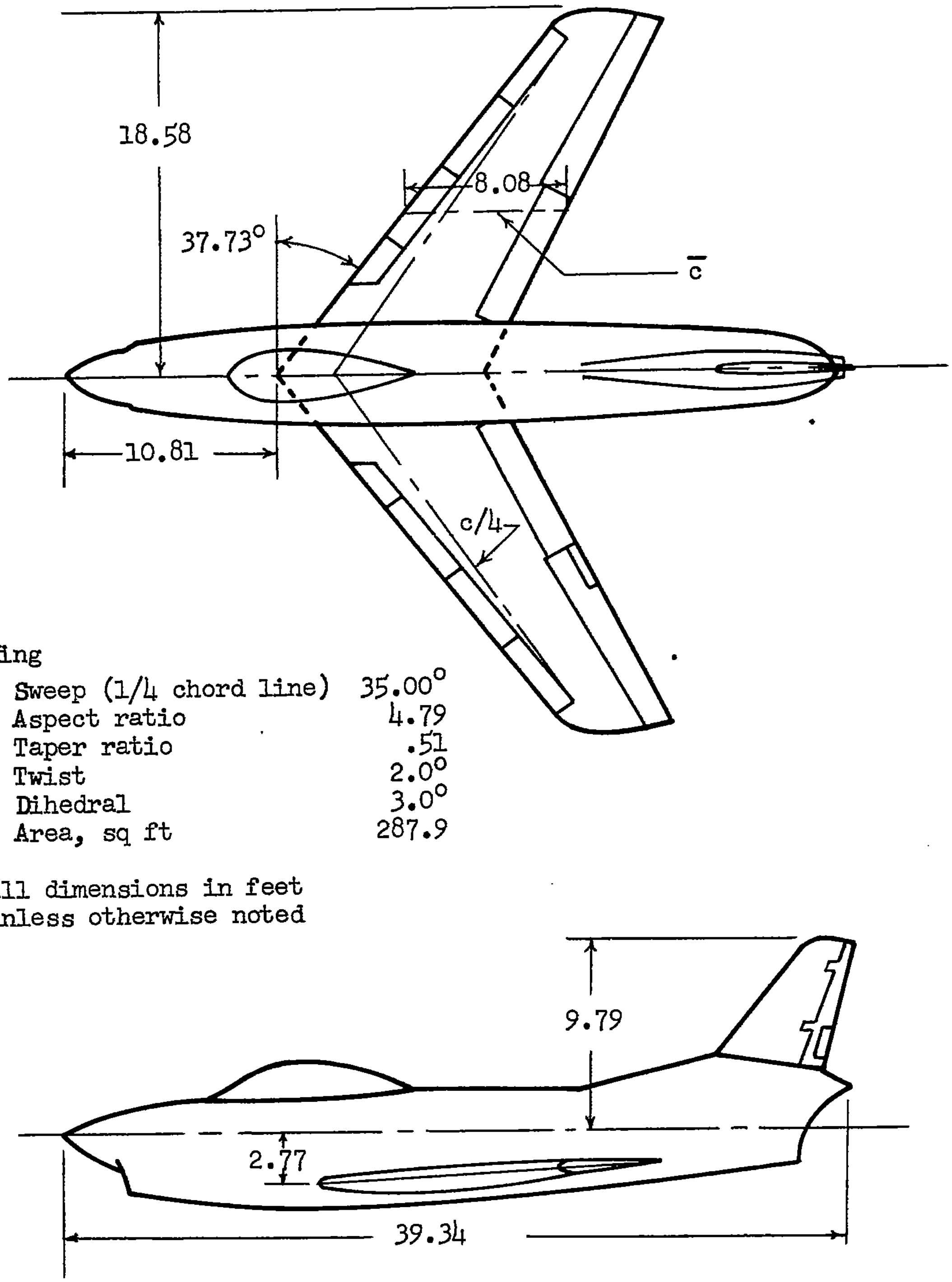
Figure 1.- The YF-86D airplane mounted in the Ames 40- by 80-foot wind tunnel.



Wing

Sweep (1/4 chord line)	35.00°
Aspect ratio	4.79
Taper ratio	.51
Twist	2.0°
Dihedral	3.0°
Area, sq ft	287.9

All dimensions in feet
unless otherwise noted

Figure 2.- General arrangement of the YF-86D airplane as tested.

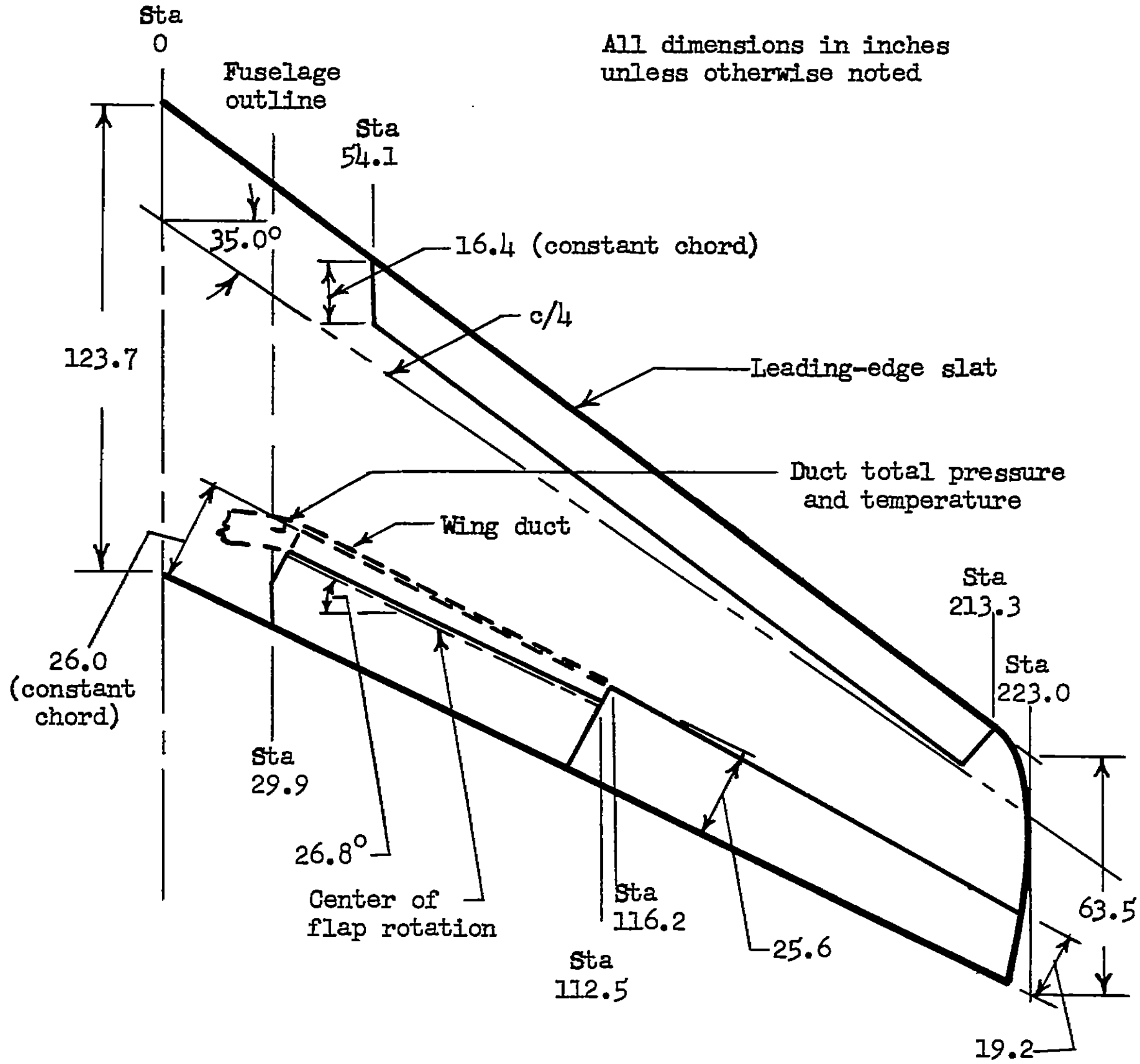
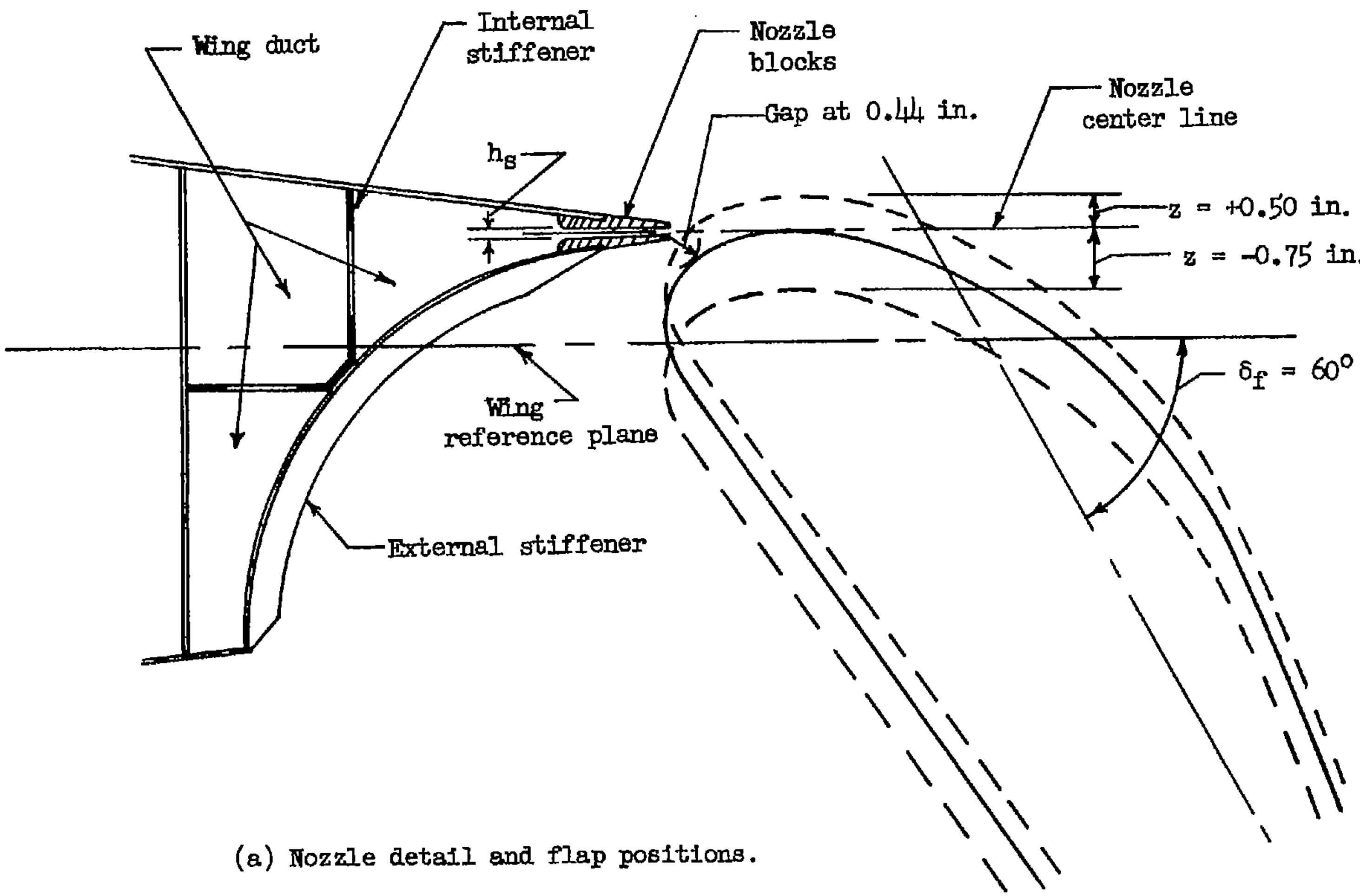
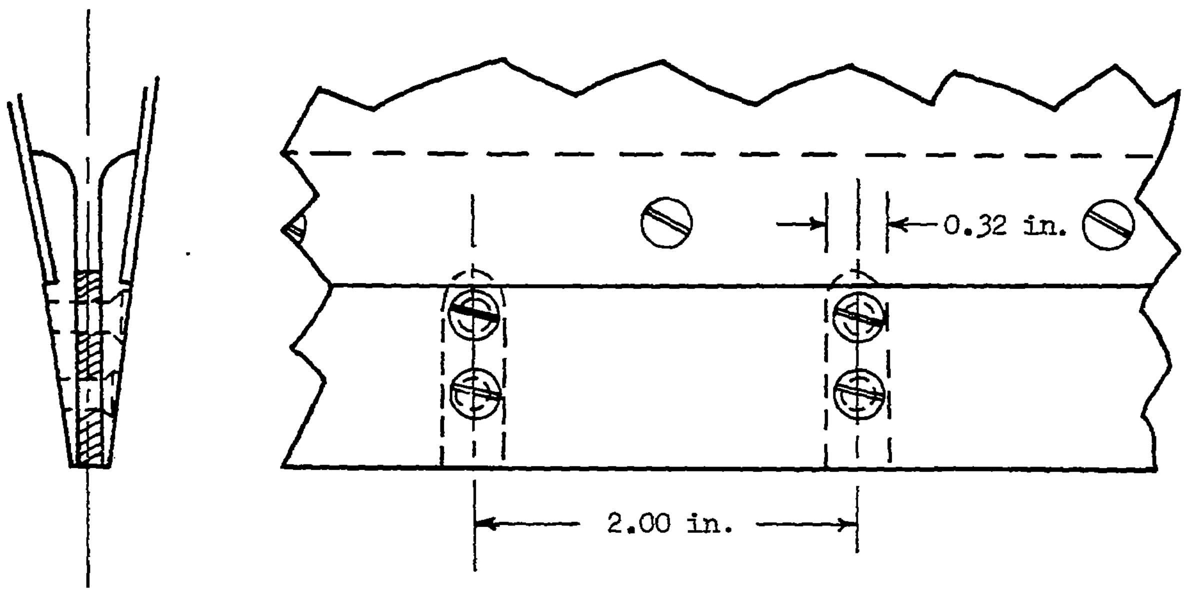


Figure 3.- Details of the wing.



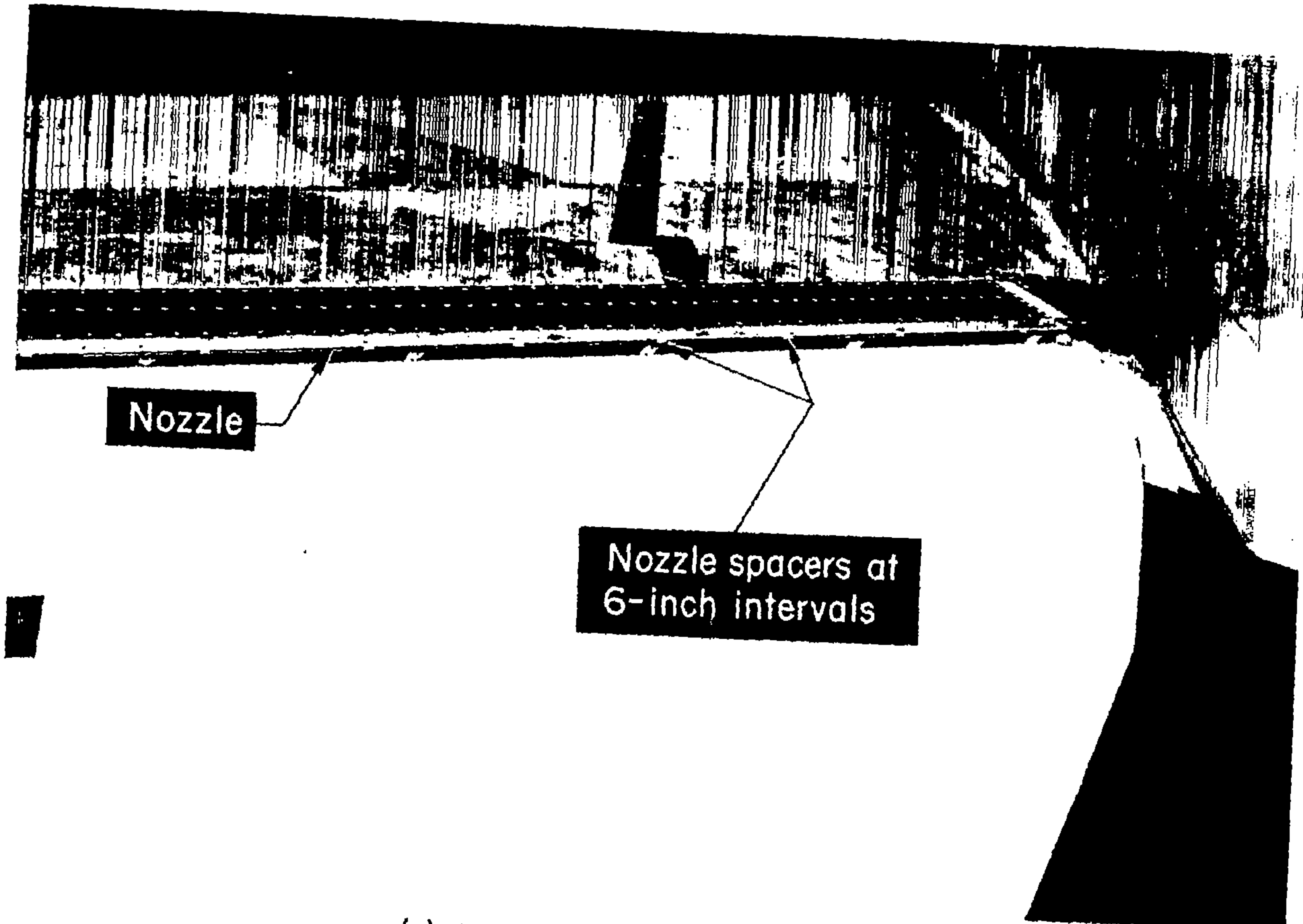
(a) Nozzle detail and flap positions.

Figure 4.- Details of flap.



(b) Nozzle spacers.

Figure 4.- Continued.



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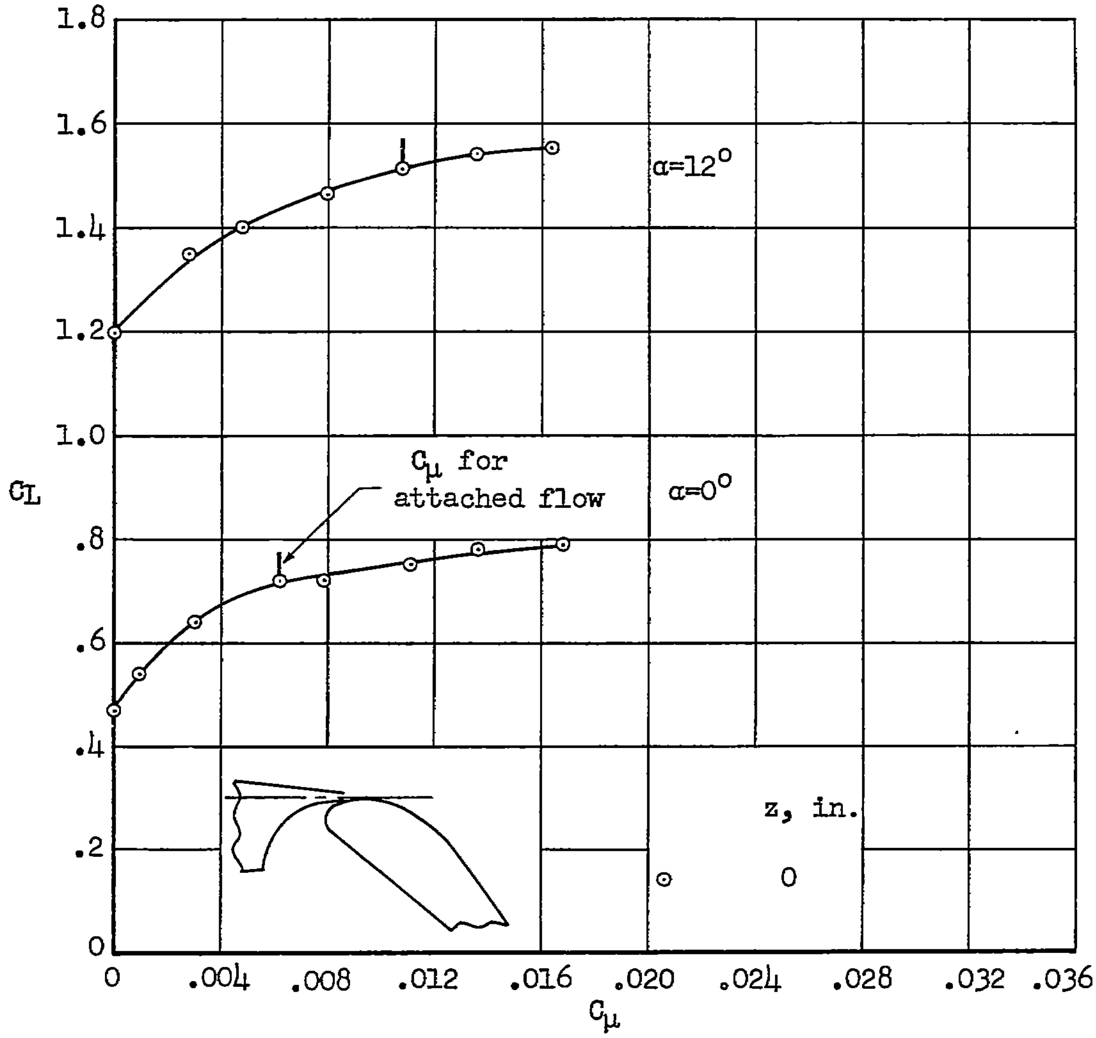
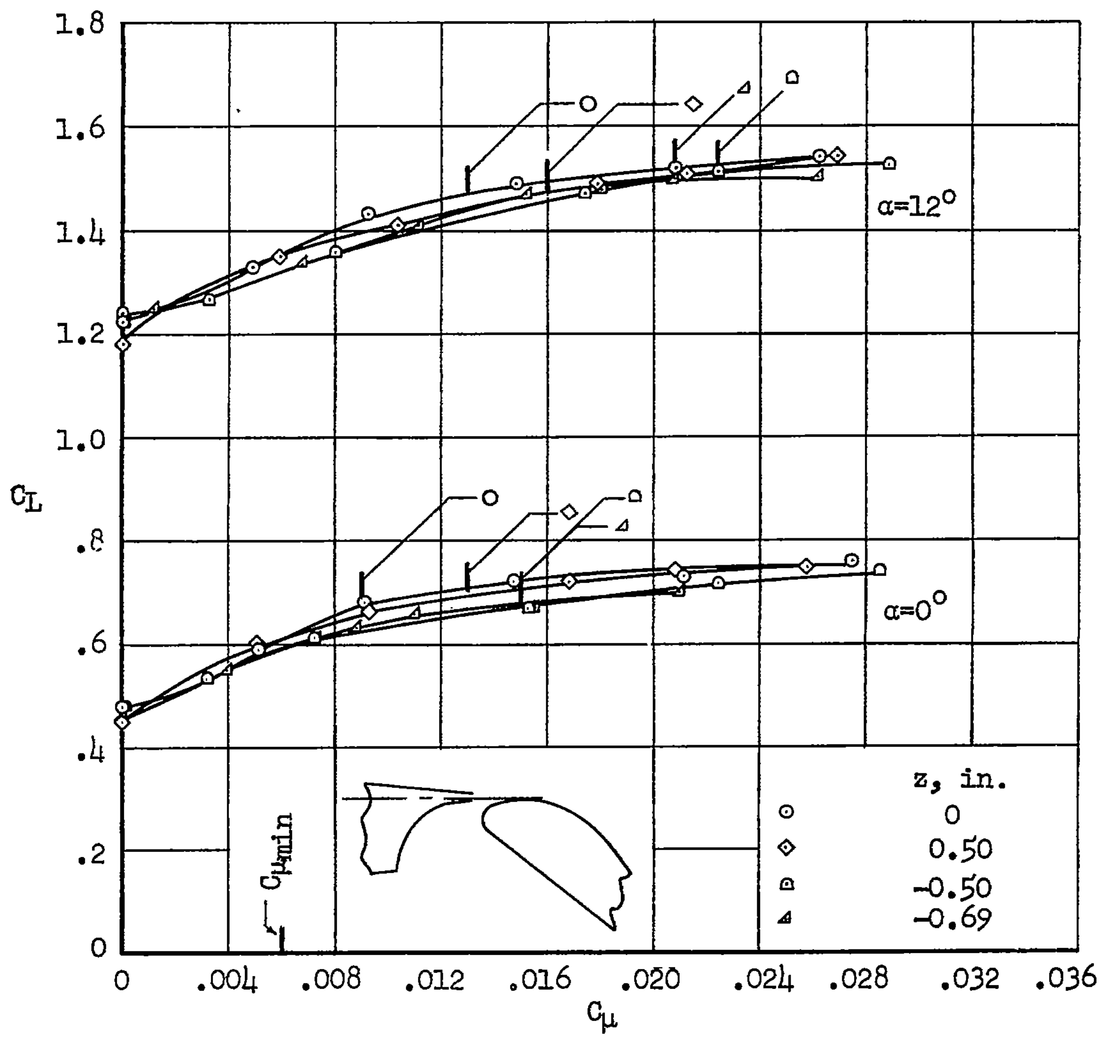
(c) Close-up view showing details of flap.

Figure 4.- Concluded.



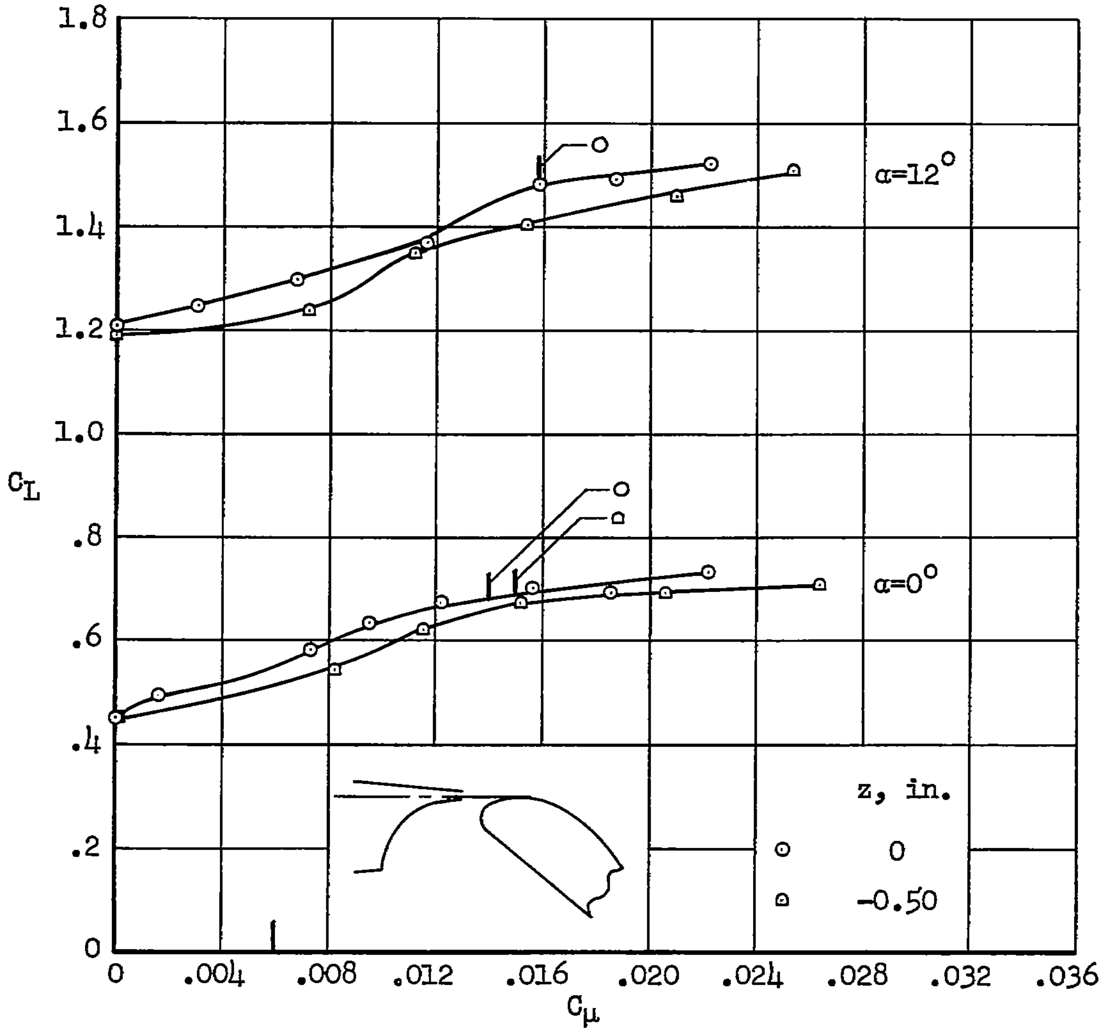
(a) No gap.

Figure 5.- Effect of flap position on C_μ requirements; $\delta_f = 45^\circ$, $h_s = 0.064$ inch.



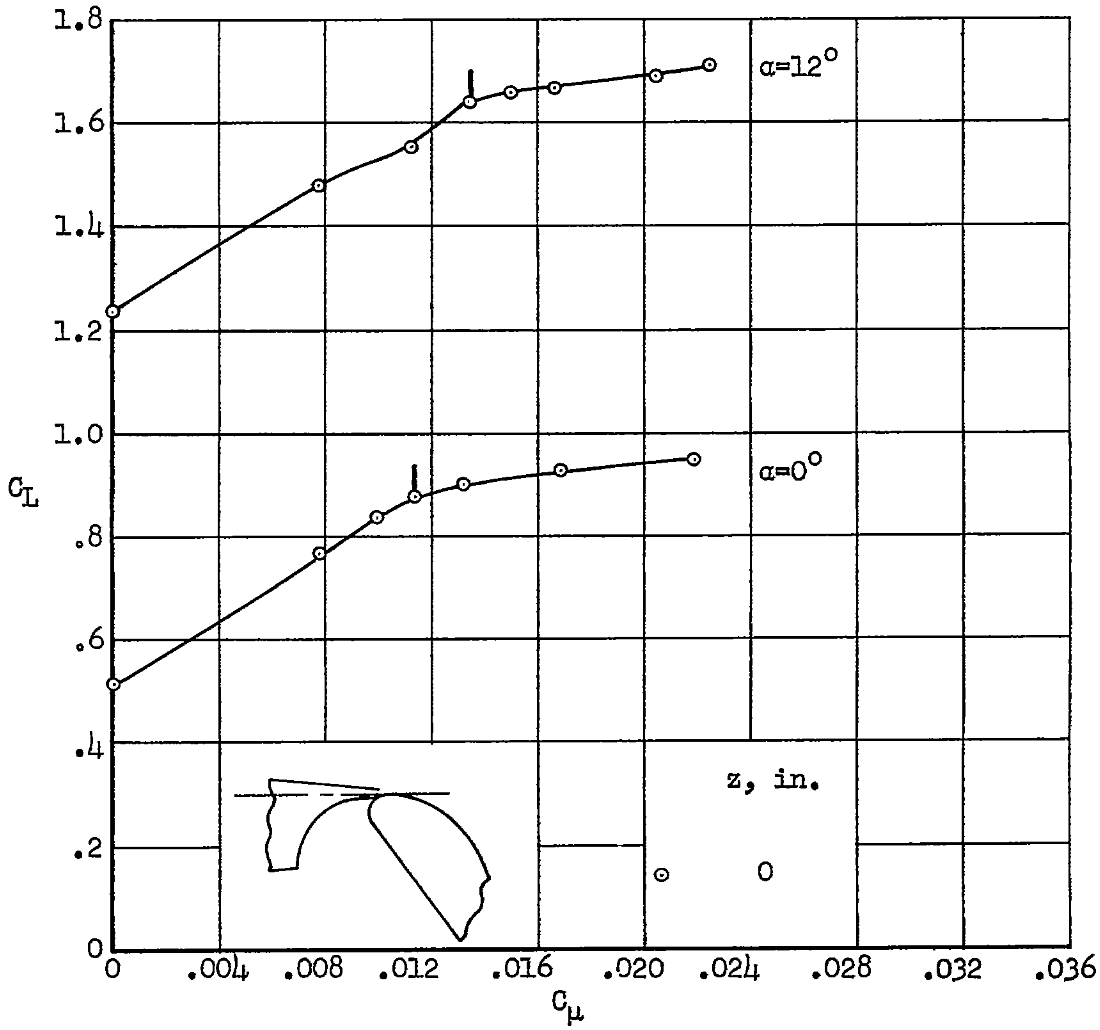
(b) Gap = 1.06 inches.

Figure 5.- Continued.



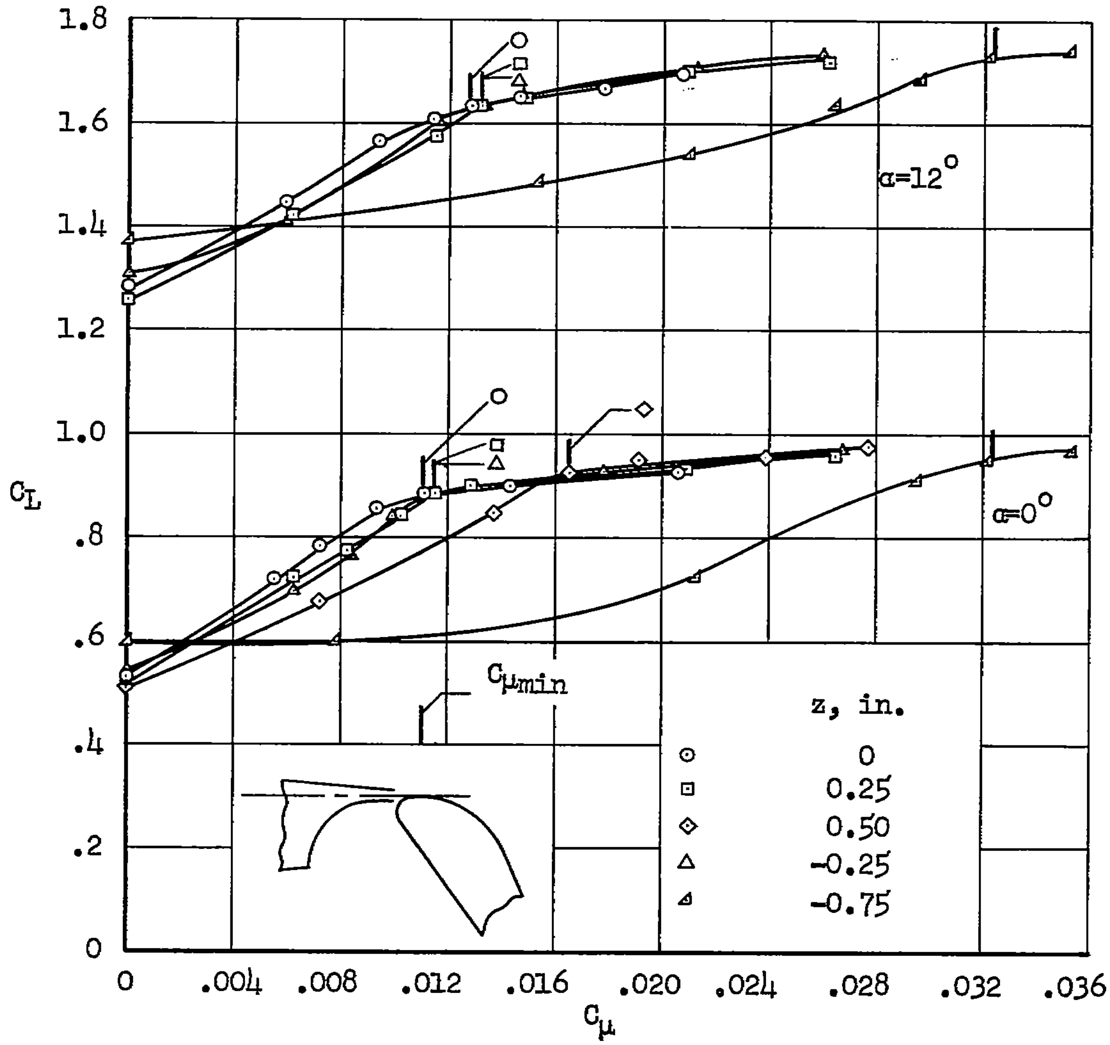
(c) Gap = 1.75 inches.

Figure 5.- Concluded.



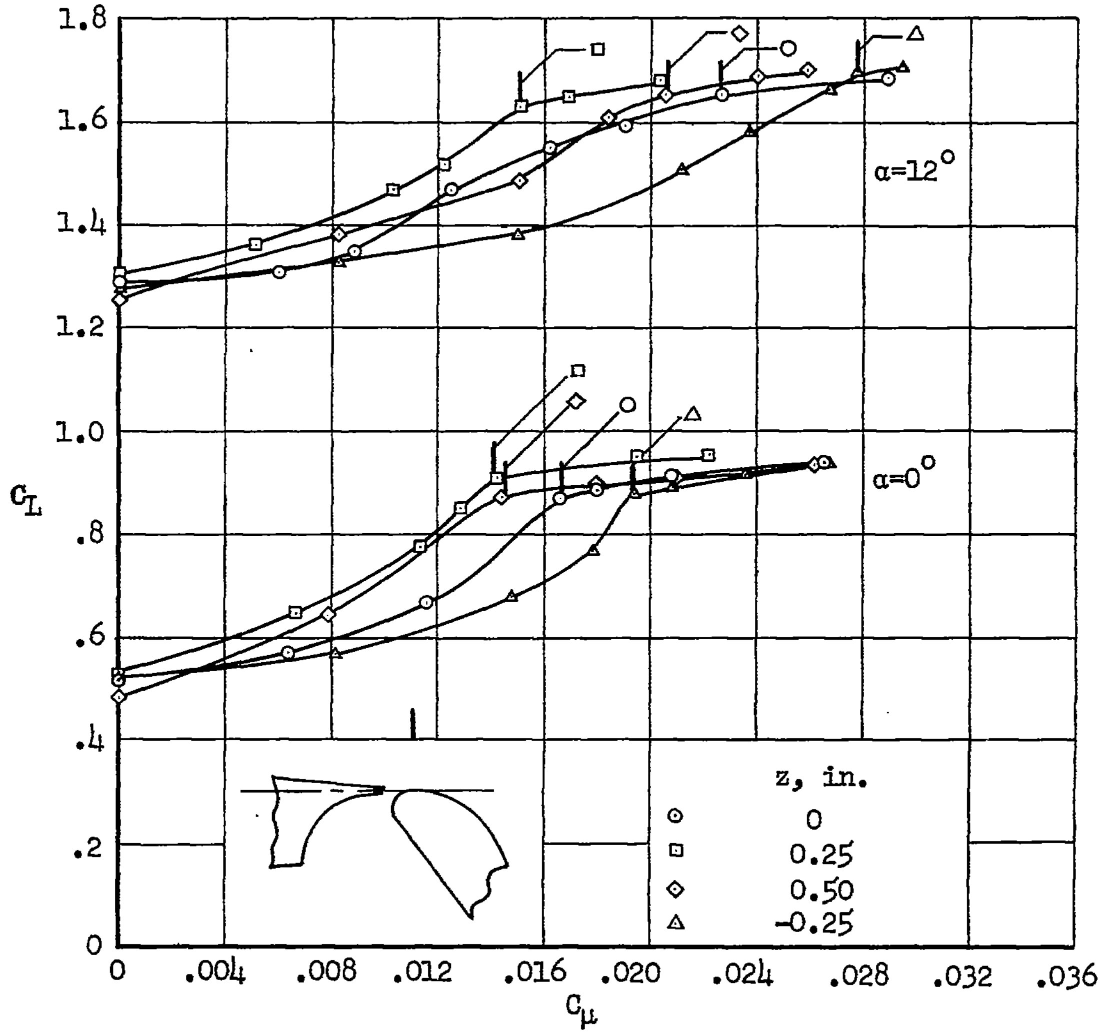
(a) No gap.

Figure 6.- Effect of flap position on C_μ requirements; $\delta_f = 60^\circ$, $h_s = 0.064$ inch.



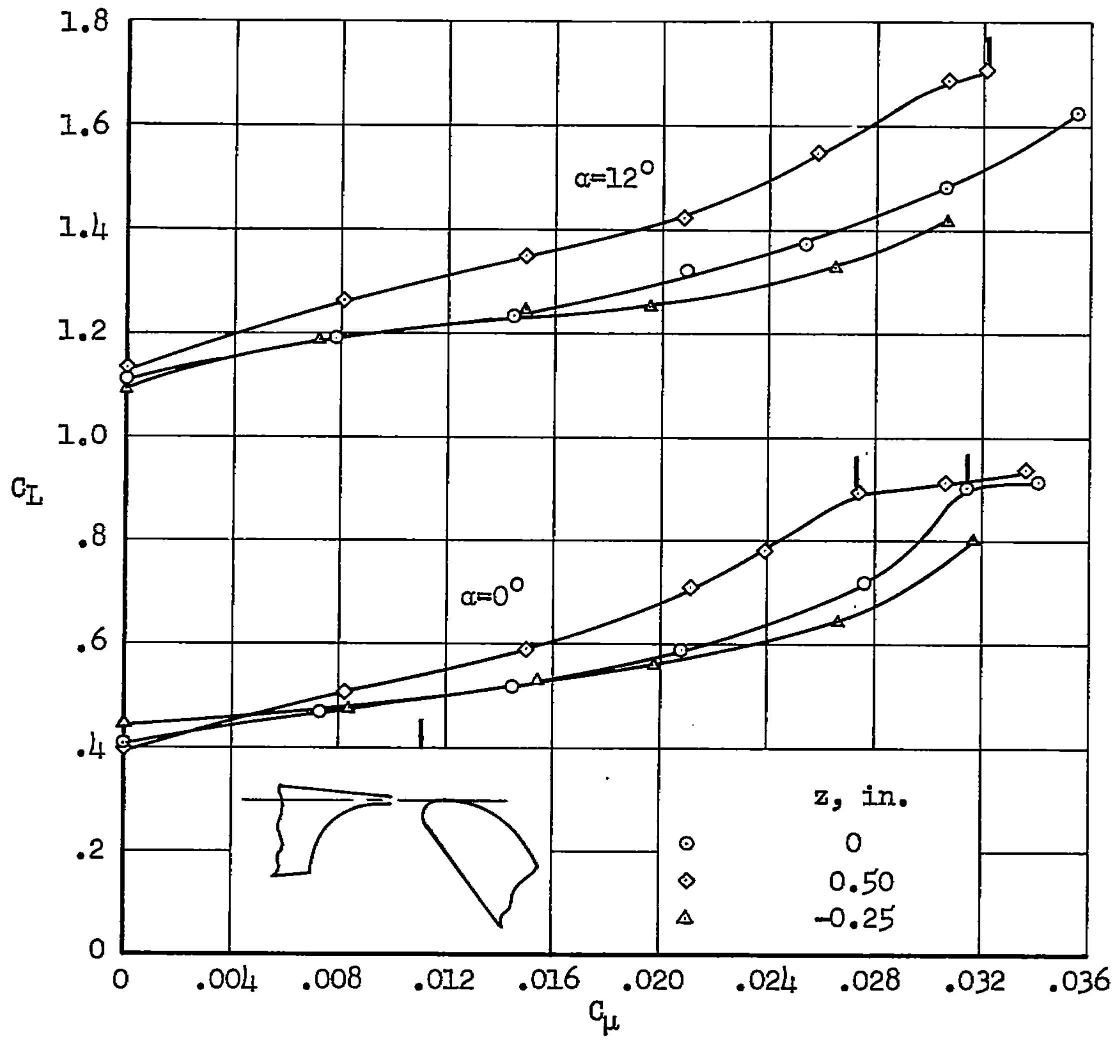
(b) Gap = 0.44 inch.

Figure 6.- Continued.



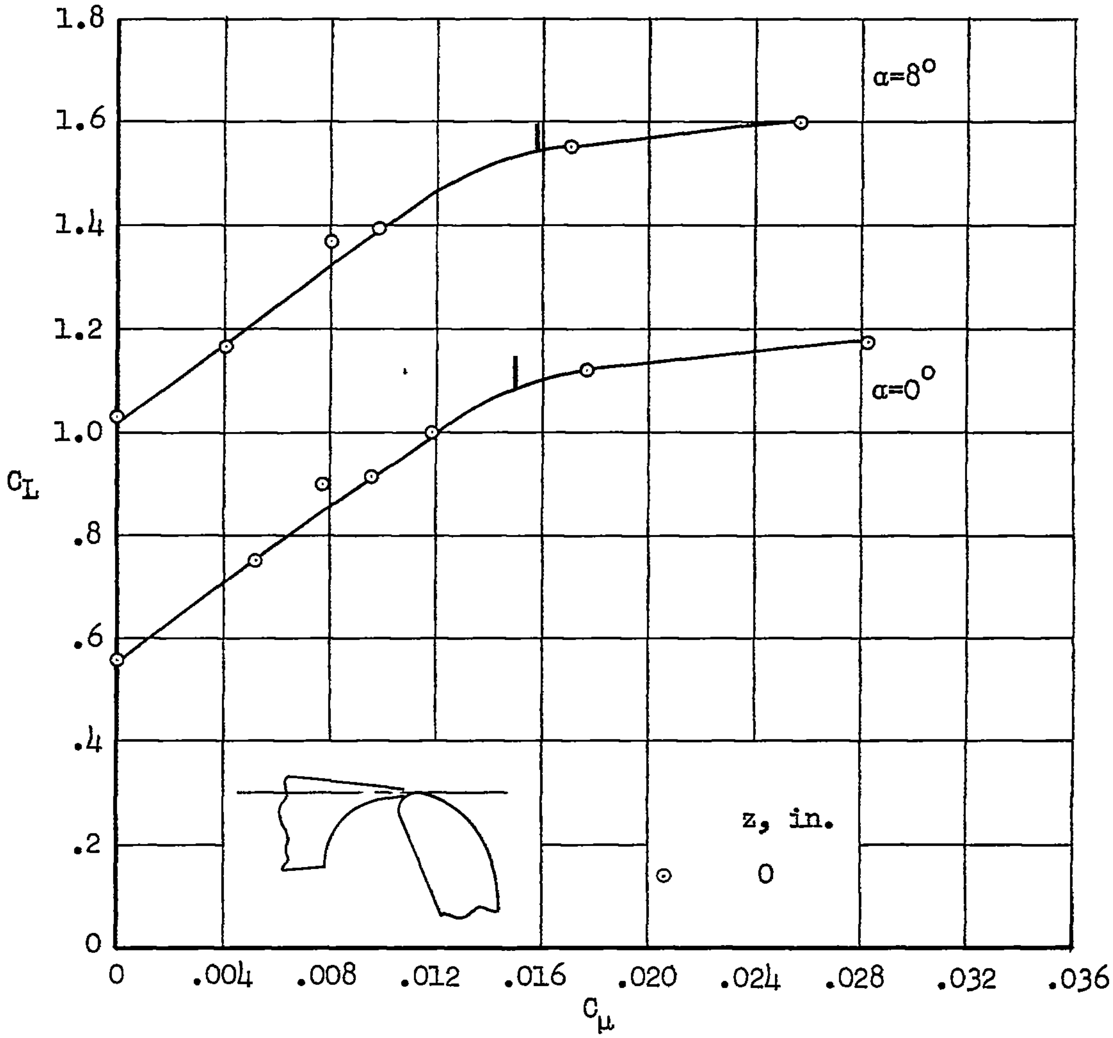
(c) Gap = 1.06 inches.

Figure 6.- Continued.



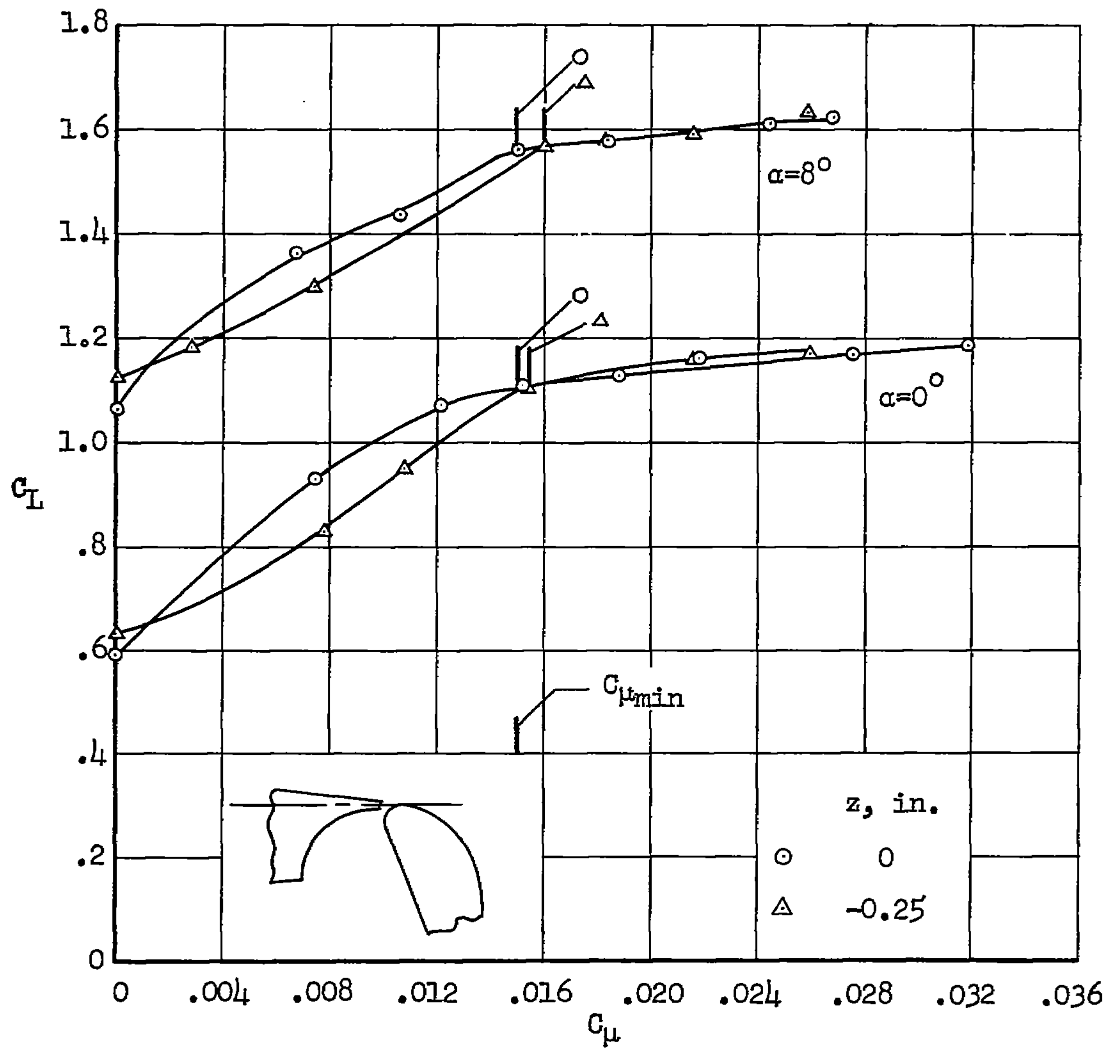
(d) Gap = 2.44 inches.

Figure 6.- Concluded.



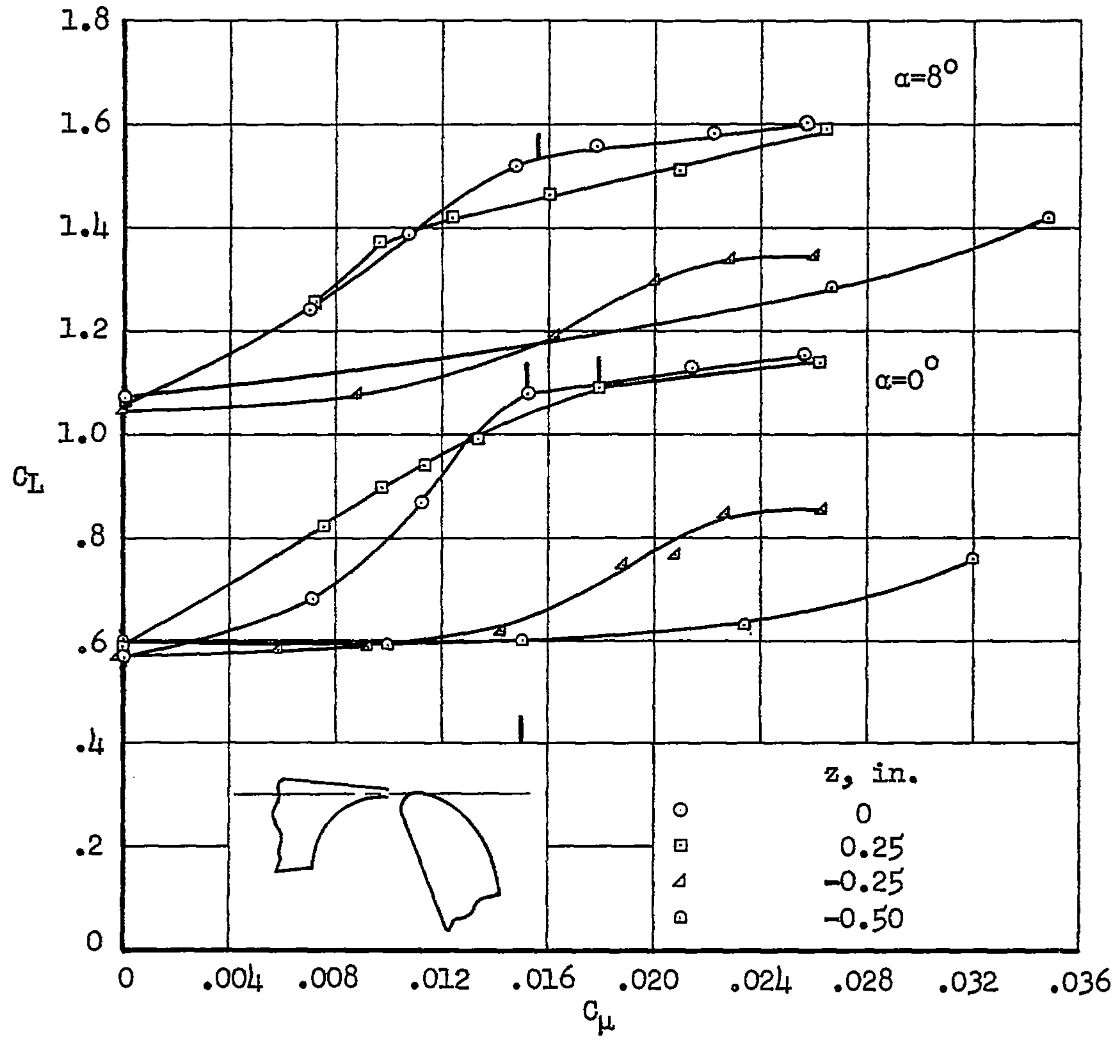
(a) No gap.

Figure 7.- Effect of flap position on C_{μ} requirements; $\delta_f = 75^{\circ}$, $h_s = 0.064$ inch.



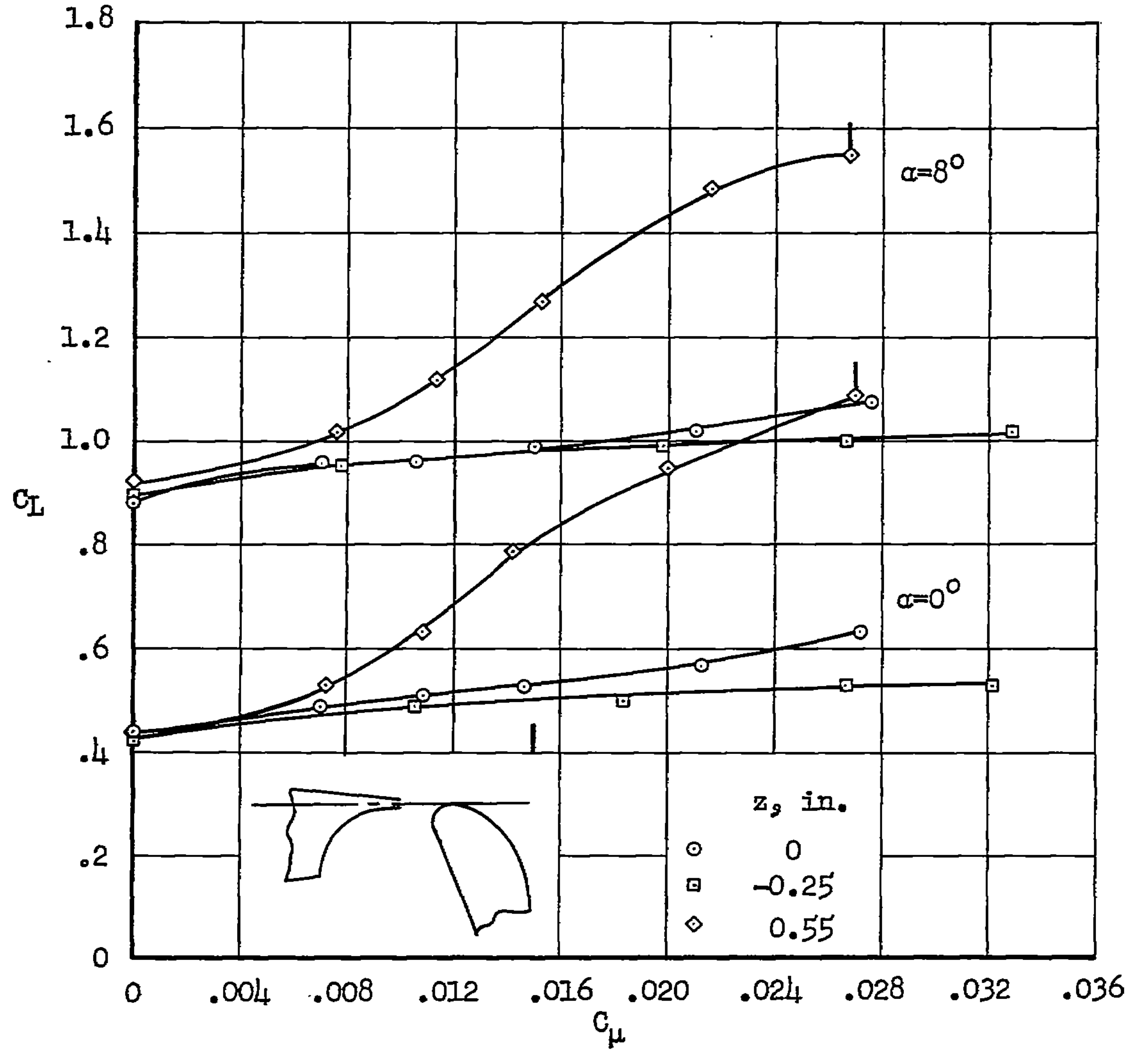
(b) Gap = 0.44 inch.

Figure 7.- Continued.



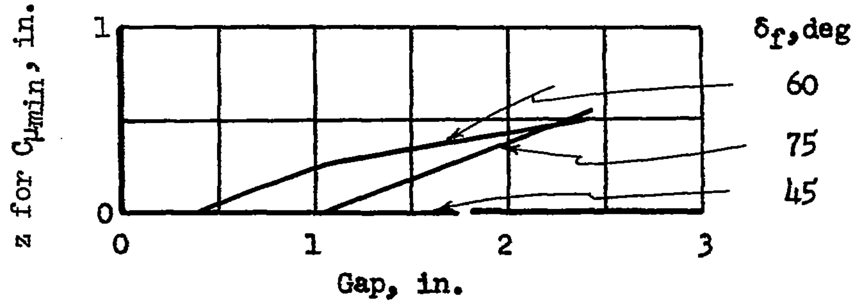
(c) Gap = 1.06 inches.

Figure 7.- Continued.

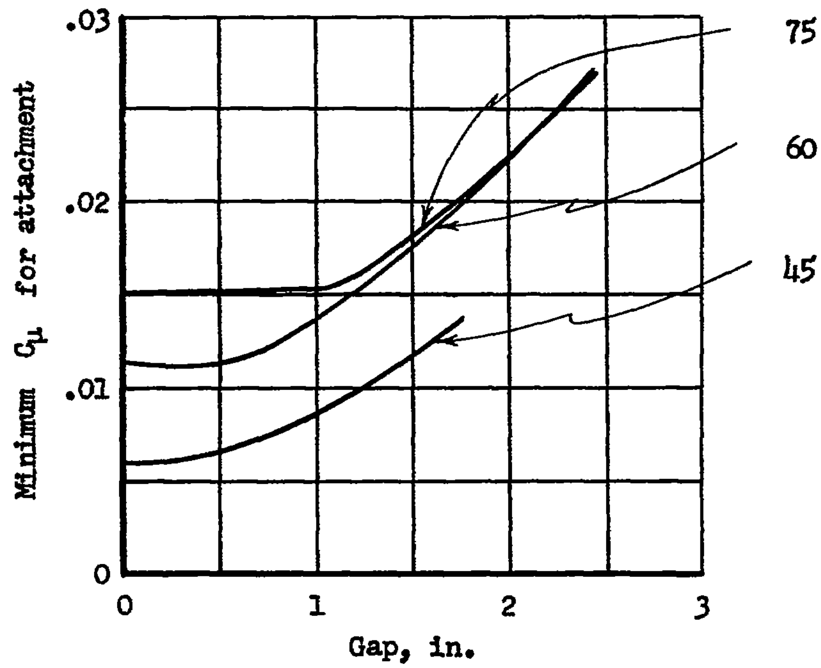


(d) Gap = 2.44 inches.

Figure 7.- Concluded.



(a) Vertical location for $C_{\mu_{min}}$.



(b) Minimum C_μ.

Figure 8.- Effect of changing flap position on $C_{\mu_{min}}$ with the flap at various deflection angles and the vertical location at which $C_{\mu_{min}}$ occurred; $\alpha = 0^\circ$.

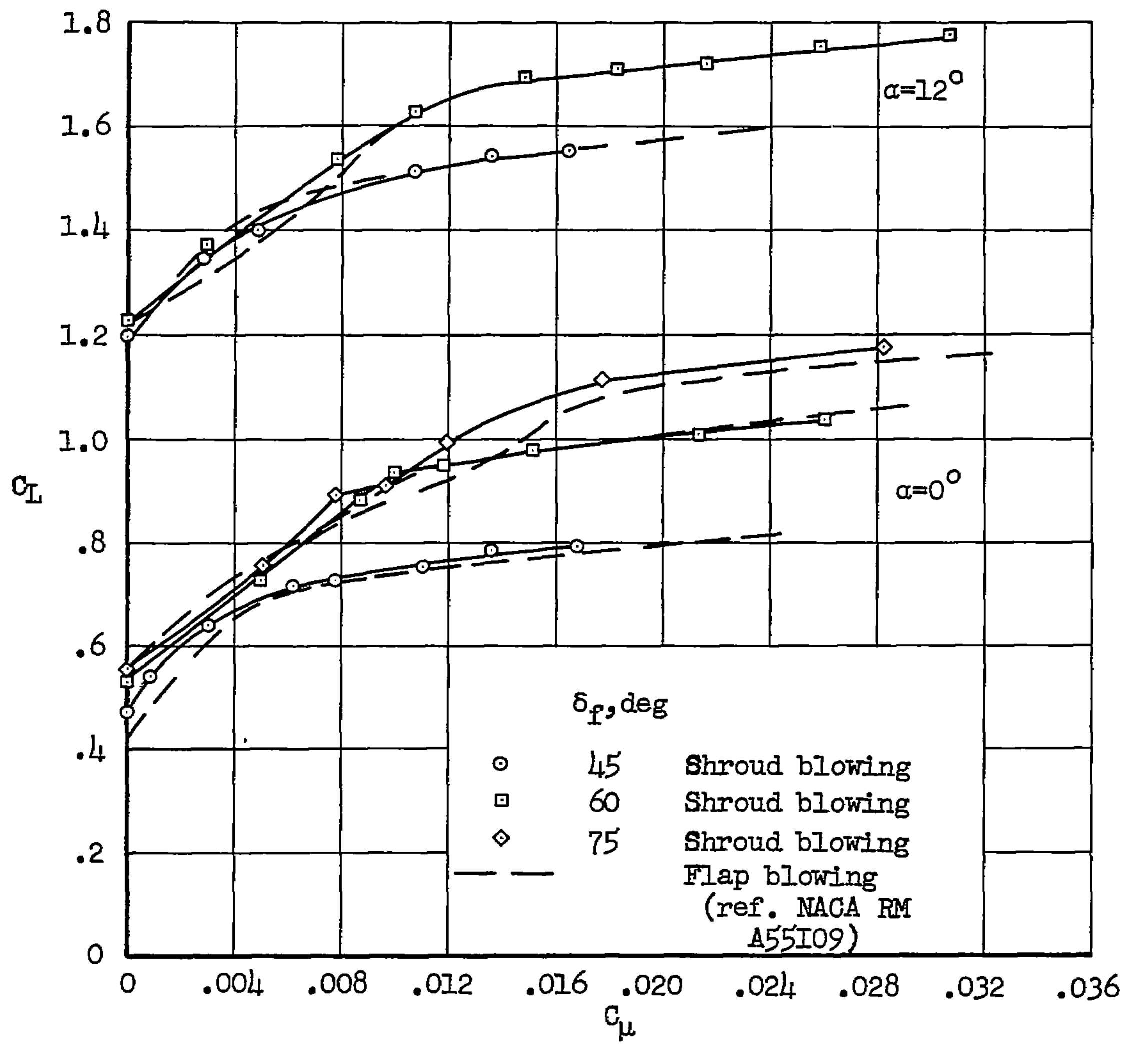
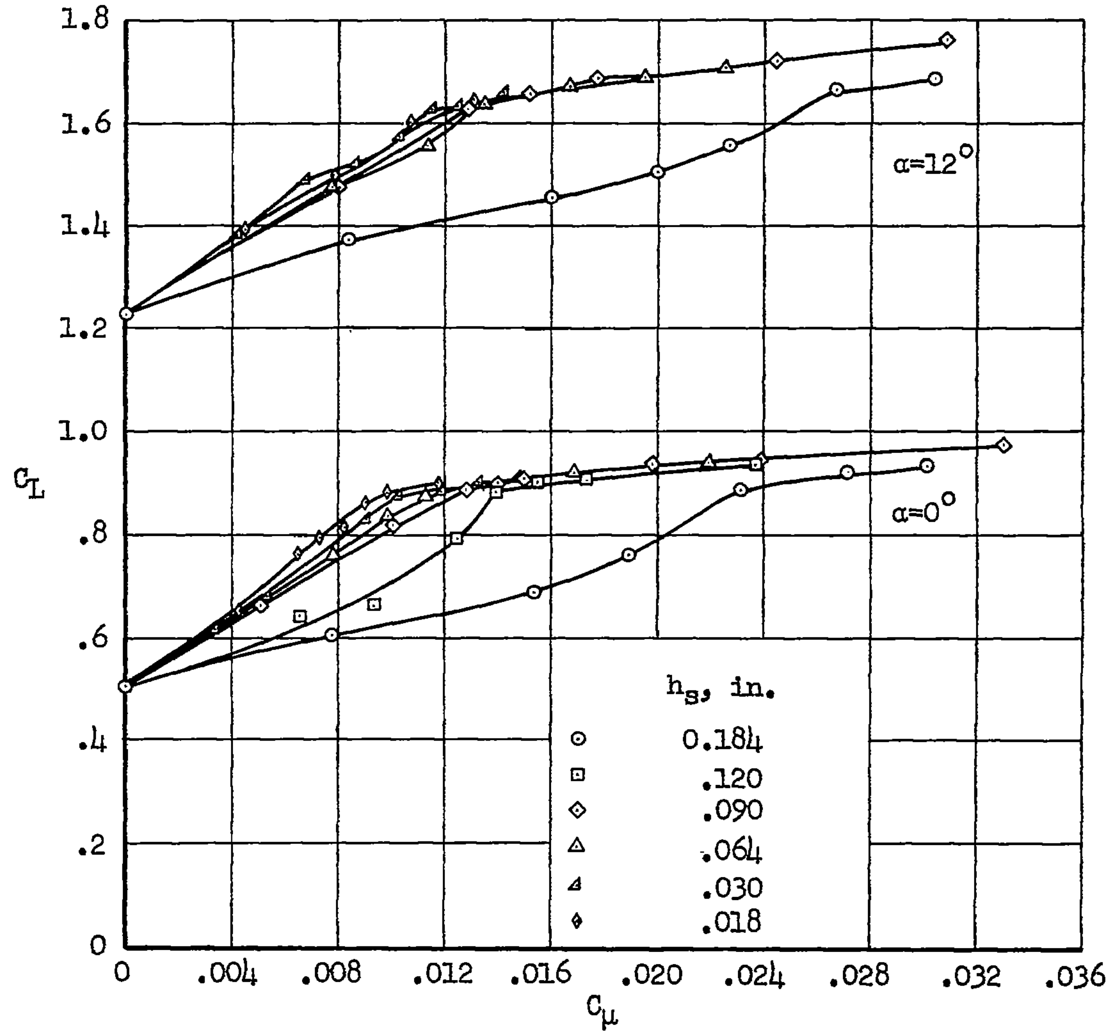
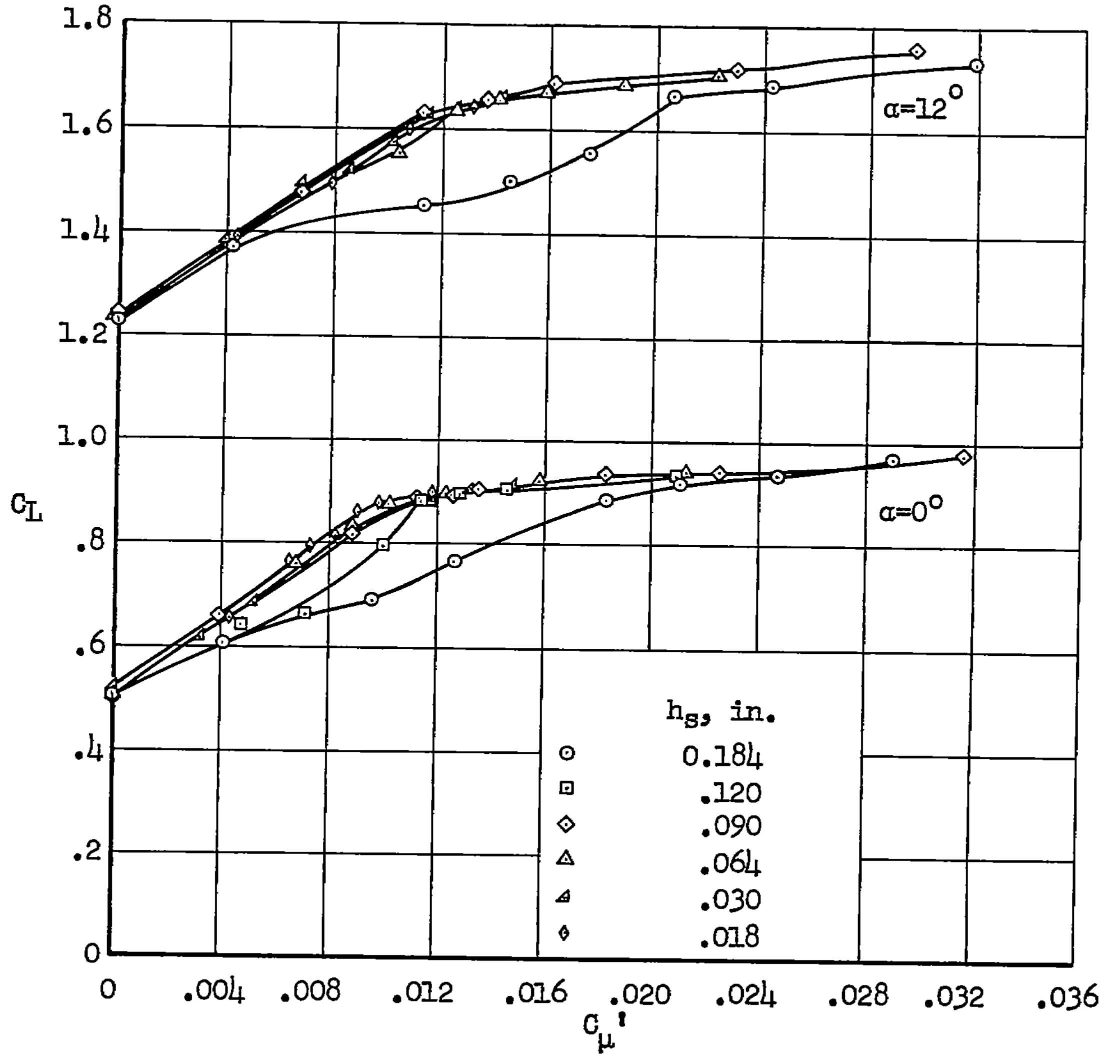


Figure 9.- Comparison of blowing flaps with the jet issuing from the shroud and from the surface of the flap; no nozzle spacers, no gap, h_s = 0.064 inch.



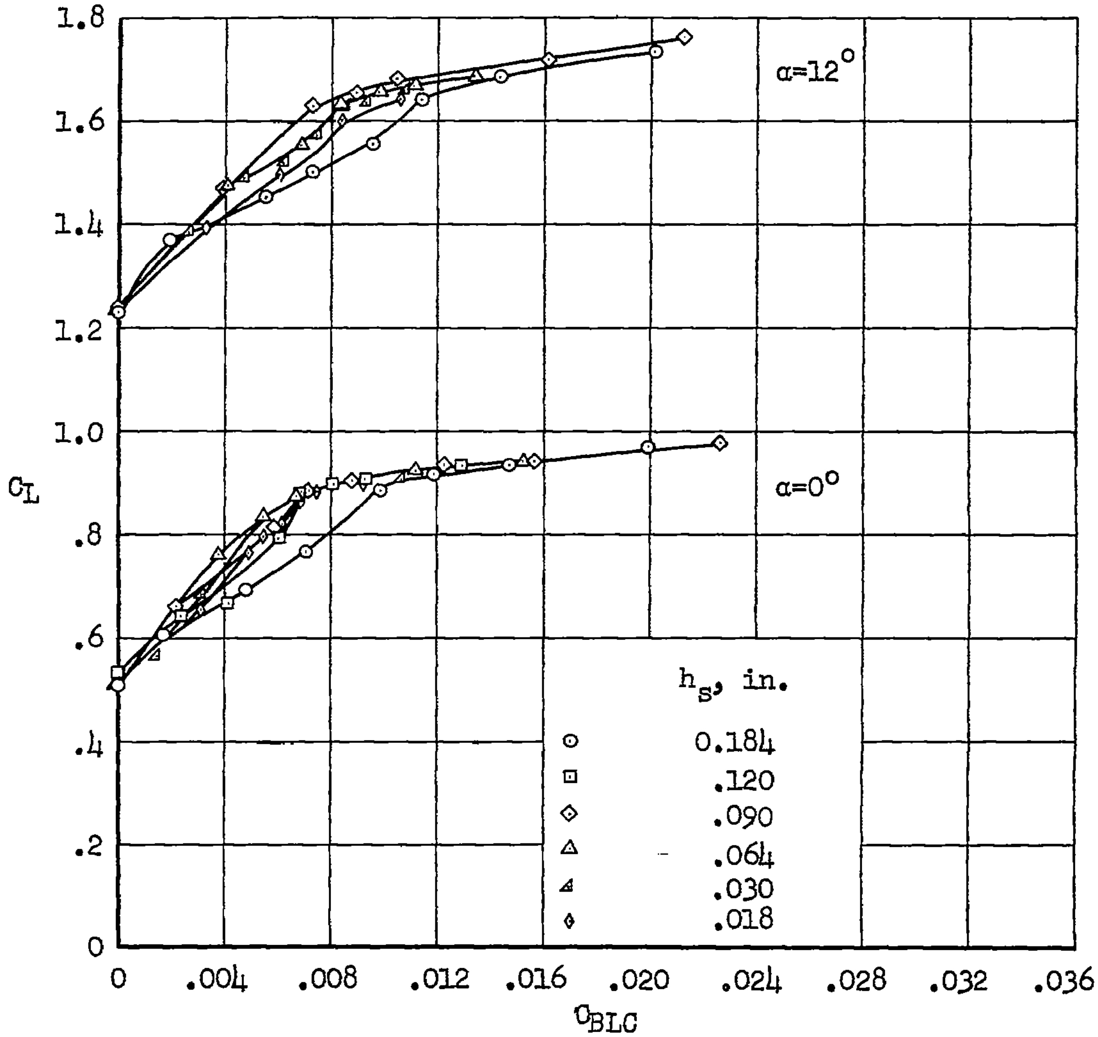
(a) C_μ computed from pressures and temperatures measured at the wing duct entrance.

Figure 10.- Correlation of parameters used to determine jet air-flow requirements; $\delta_f = 60^\circ$, no gap.



(b) C_μ' computed from pressures corrected to nozzle conditions.

Figure 10.- Continued.



(c) C_{BLC} computed from pressures corrected to nozzle conditions.

Figure 10.- Concluded.

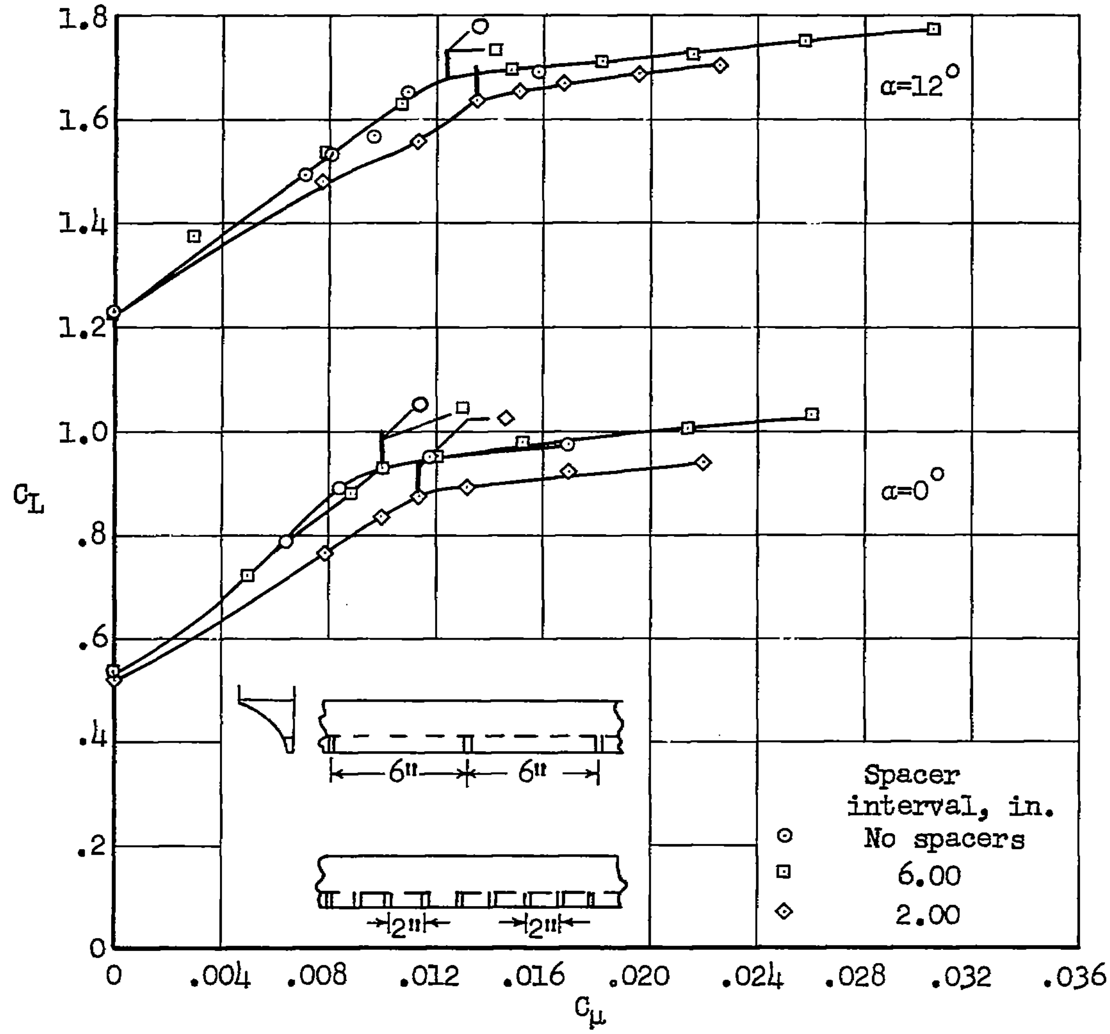


Figure 11.- Effect of spacers 0.32 inch wide inside the nozzle at various intervals along the flap span; $\delta_f = 60^\circ$, h_s = 0.064 inch, no gap.

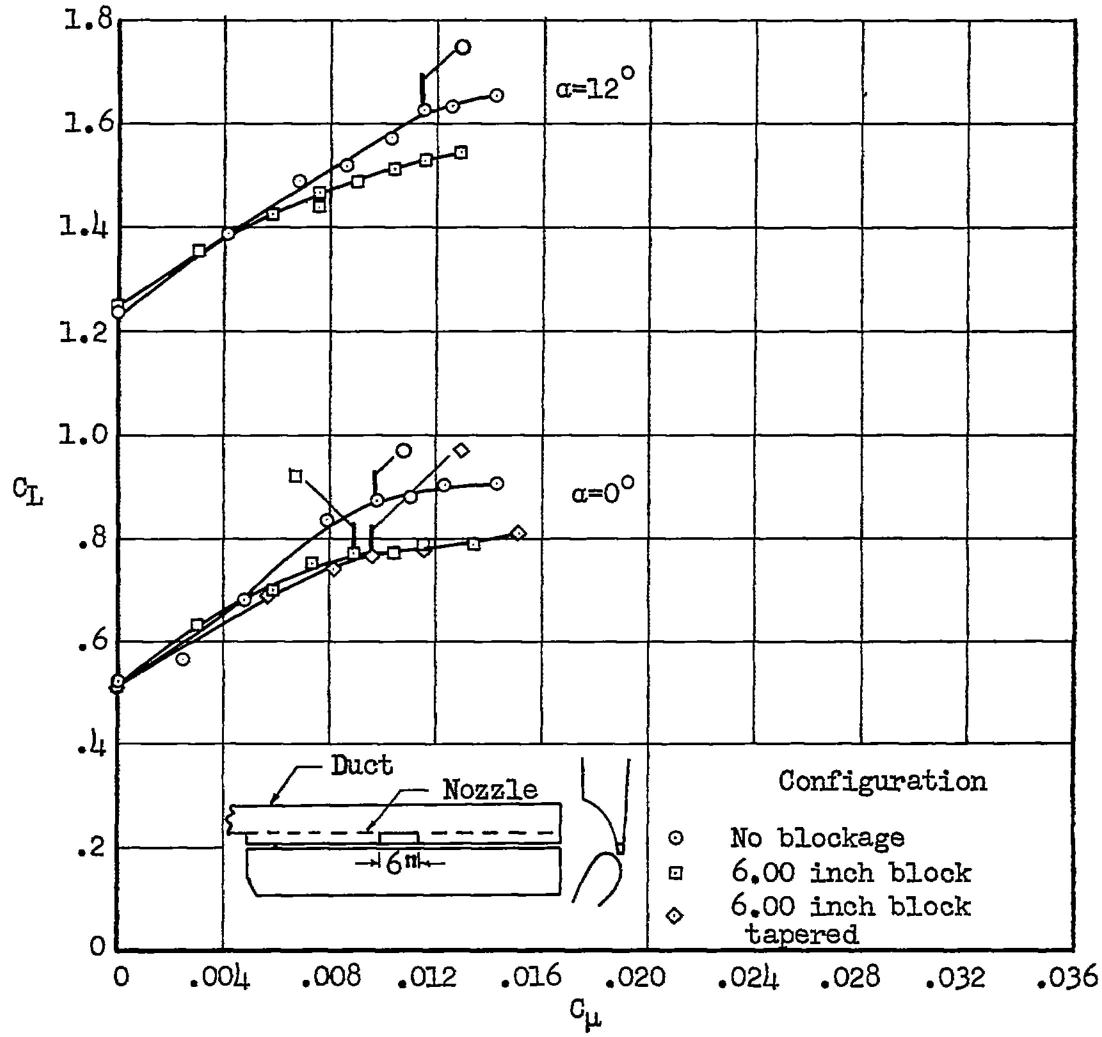


Figure 12.- Effect of nozzle blockage 6 inches wide at the center of the flap span; $\delta_f = 60^\circ$, $h_s = 0.032$ inch, no gap, nozzle spacers at 2-inch intervals.

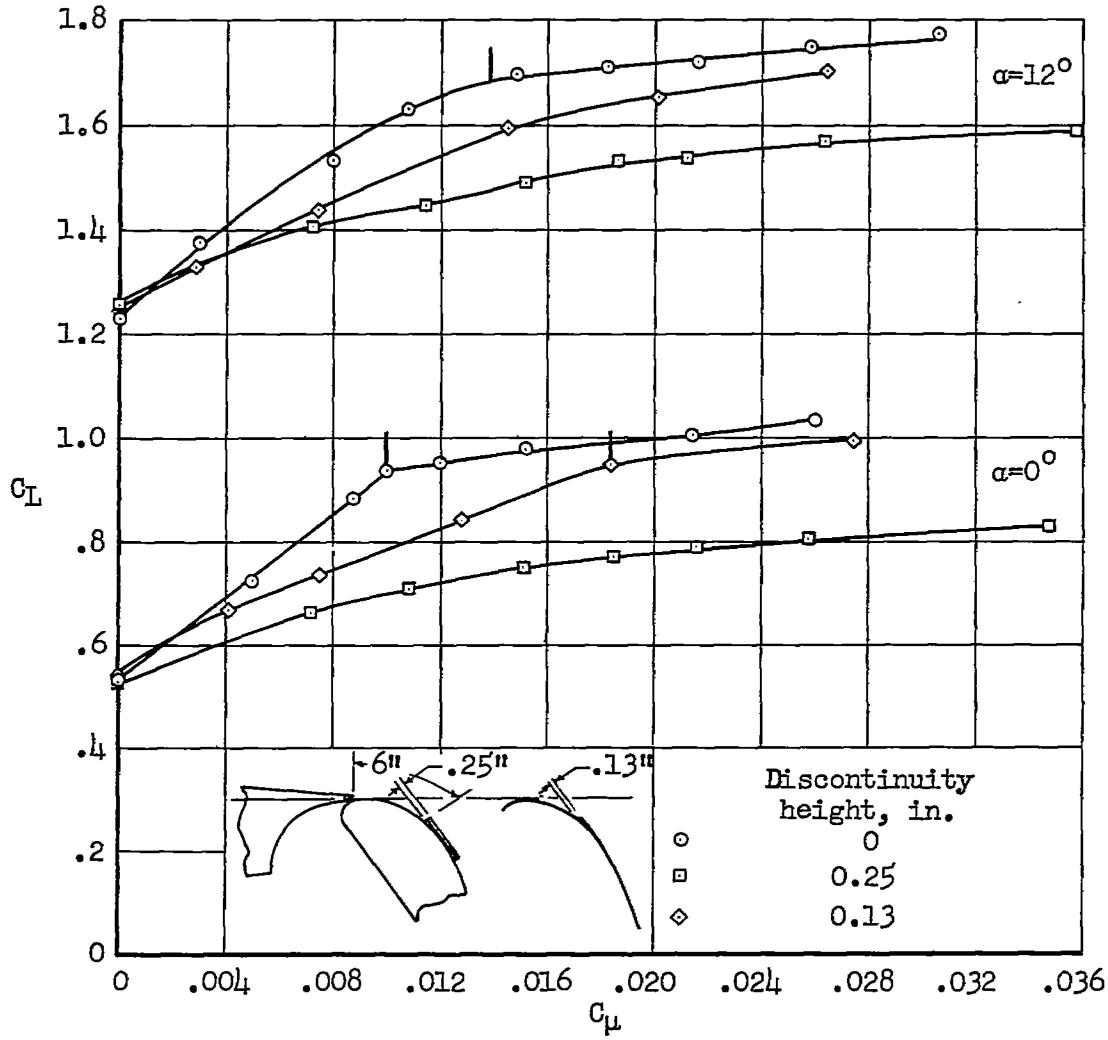


Figure 13.- Effect of discontinuity on the flap upper surface; $\delta_f = 60^\circ$, $h_s = 0.064$ inch, no gap, nozzle spacers at 6-inch intervals.

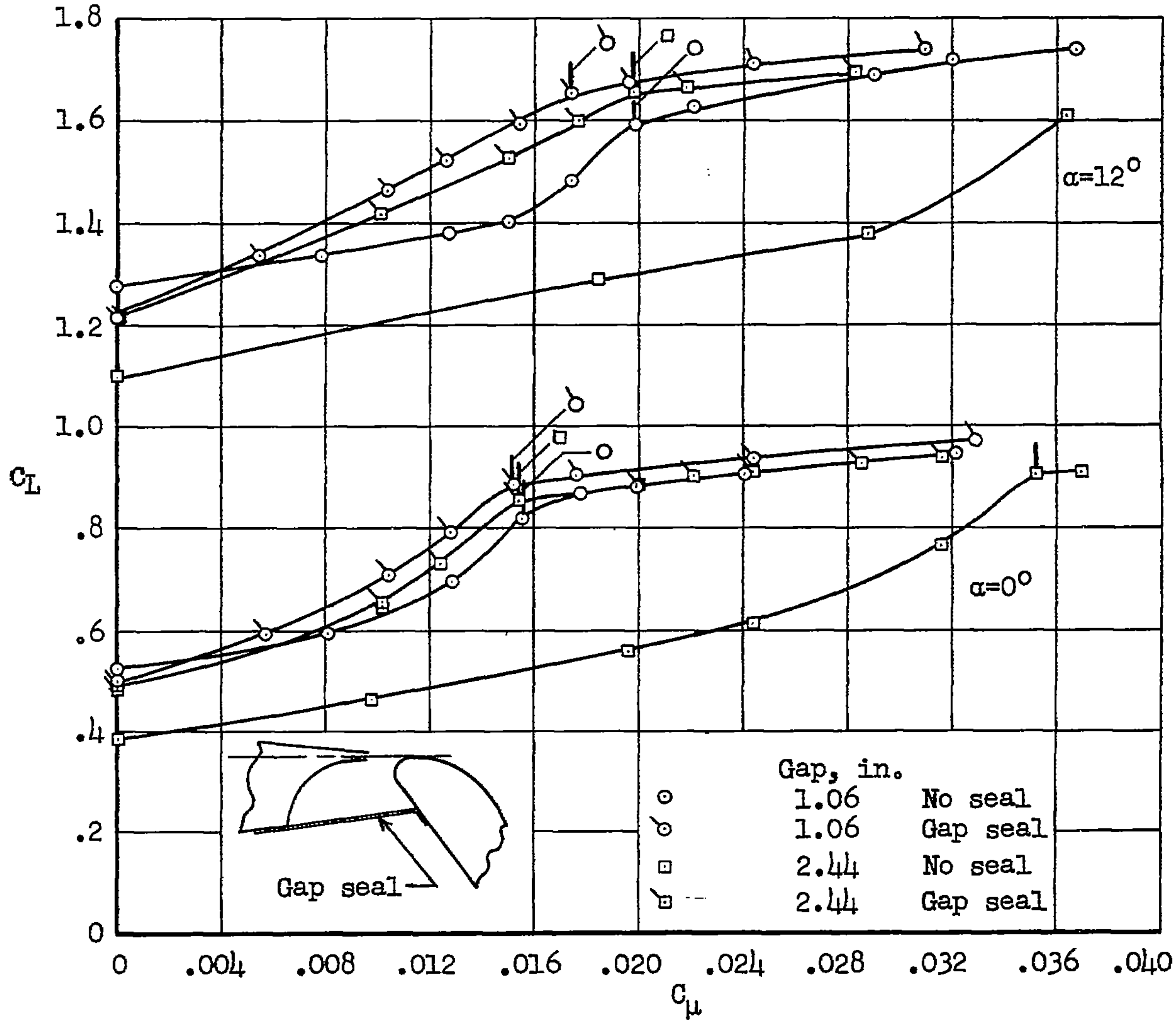


Figure 14.- Effect of gap seal; $\delta_f = 60^\circ$, $h_s = 0.090$ inch, $z = 0$.